Received: 02.11.2024. Revised: 09.02.2025. Accepted: 12.03.2025

Bulletin of the Kyrgyz National Agrarian University

Vol. 23, No. 1. 2025

Journal homepage: https://knau-bulletin.com/en

UDC 636:611:575:636.9

DOI: 10.63621/bknau./1.2025.38

Morphostructural characteristics of secondary immunogenesis organs in wild boars

Marasulbek Amirakulov

PhD in Biological Sciences, Associate Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Str., Bishkek, Kyrgyz Republic
https://orcid.org/0000-0002-2432-4670

Kuban Arbaev*

Doctor of Veterinary Sciences, Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Str., Bishkek, Kyrgyz Republic
https://orcid.org/0000-0003-3910-5283

Baktybek Azhybekov

PhD in Veterinary Sciences, Associate Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Str., Bishkek, Kyrgyz Republic
https://orcid.org/0000-0002-7079-6791

Lyudmila Lykhina

PhD in Veterinary Sciences, Associate Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Str., Bishkek, Kyrgyz Republic
https://orcid.org/0000-0002-9371-8278

Rasida Karabaeva

PhD in Veterinary Sciences, Associate Professor
Kyrgyz National Agrarian University named after K.I. Skryabin
720005, 68 Mederov Str., Bishkek, Kyrgyz Republic
https://orcid.org/0000-0001-5845-8020

Abstract. To analyse the involvement of immune cells in the pathogenesis of diseases of various aetiologies, and to inform therapeutic and preventive interventions, it is essential to understand the normal morphology of the immune system organs and tissues. This study presented the findings of a morphological investigation of the secondary (peripheral) immune system organs in the Asian wild boar subspecies (*Sus scrofa nigripes*) inhabiting the forest-steppe region of the Moskva District, Chüy Region, Kyrgyz Republic. This research aimed to identify the general morphological and functional features of the lymphoid structures of the spleen, mesenteric lymph nodes, and haemolymph nodes in healthy animals. Study materials were collected from three sexually mature wild boars. Anatomical and histological methods were employed to achieve the study aim. Anatomical methods were used to determine the syntopy, shape, colour, and consistency of these organs. Histological studies were carried out using standard techniques: haematoxylin and eosin staining was employed to examine the general structural organisation of the organs, while Van Gieson's method was used to differentiate muscular and connective tissue

Suggested Citation: Amirakulov, M., Arbaev, K., Azhybekov, B., Lykhina, L., & Karabaeva, R. (2025). Morphostructural characteristics of secondary immunogenesis organs in wild boars. *Bulletin of the Kyrgyz National Agrarian University*, 23(1), 38-49. doi: 10.63621/bknau./1.2025.38.

*Corresponding author

elements. Light microscopy was used to analyse the stromal and parenchymal structure, cellular composition, and morphofunctional state of lymphoid formations. The study established the morphofunctional condition and morphological characteristics of the spleen, lymph nodes, and haemolymph nodes in sexually mature Asian wild boar subspecies. The findings represented the morphological norm for the secondary immune system organs of this subspecies. These results may serve as a reference framework for future experimental and applied research in the morphology and immunology of organs and tissues in wild boars, both under normal conditions and in pathological states. The data may also be of practical use to veterinary specialists and biologists engaged in functional, ecological, and comparative morphology of organs in domestic and wild animals

Keywords: spleen; lymph nodes; haemolymph nodes; trabeculae; organ parenchyma; lymphoid follicles; lymphocytes

Introduction

The Asian wild boar subspecies (*Sus scrofa nigripes*) is one of the largest wild animals inhabiting the mountainous steppe territories of the Kyrgyz Republic and serves as a primary target for sport hunting among commercial species. According to data from the National Statistical Committee of the Kyrgyz Republic (n.d.), the population of these animals showed steady growth between 2019 and 2023, reaching 3,089 individuals in 2023. The wild boar (*Sus scrofa*) is recognised as one of the world's most widely distributed omnivorous mammals, present on all continents except Antarctica (Markov *et al.*, 2022). Despite its extensive range, there is currently a lack of comprehensive scientific studies focusing on the morphological and functional characteristics of both the primary and secondary organs of its immune system under normal conditions. Furthermore, it should be noted that this topic remains relatively understudied in current scientific practice. The available literature presents only isolated studies on this subject: for instance, A. Panphilof *et al.* (2005) investigated the cytoarchitecture of mesenteric lymph nodes; Y. Bozkurt *et al.* (2019) conducted an analysis of the histological and immunohistochemical characteristics of abdominal and thoracic lymph nodes; and E. Chirkova *et al.* (2023) examined the anatomical structure of the heart and spleen in this species. A. Marunchyn *et al.* (2023) studied the clinical manifestations of splenic tumour lesions and associated structural changes.

It is recognised that the wild boar is the direct ancestor and close relative of all known breeds of domestic pigs (Getmantseva *et al.*, 2020). Unlike other domesticated animals, pigs have undergone the fewest genetic alterations. Compared to their wild counterparts, they are frequently utilised as subjects in biomedical and bio-veterinary experiments (Lunney *et al.*, 2021). Scientists in the field of porcine immunomorphology have achieved significant progress, leading to the accumulation of extensive data regarding the morphology and morphofunctional state of lymphoid organs and tissues under normal conditions and various pathological states. Information concerning these investigations is detailed in the article by R. Pabst (2020). Numerous high-quality studies have been conducted on the morphology and morphofunctional state of secondary lymphoid organs and tissues in domestic pigs. For instance, age-related changes in mucosa-associated lymphoid tissue (MALT) of the conjunctiva in pigs were investigated by A. Irgashev *et al.* (2020). They established that conjunctiva-associated lymphoid tissue in pigs contains all the necessary structures and cells required for an immune response and the protection of parocular tissues of the eye. In addition, V. Grigoryev *et al.* (2023) examined the histogenesis and functional development of the thymus and lymph nodes in piglets during the prenatal period. It was revealed that the thymus, as a central organ of the immune system, begins to form in pig foetuses from the 30th day of embryonic development, while the lymph nodes, acting as sites of lymphoid haematopoiesis and components of the peripheral immune system, attain morphofunctional maturity by the 70th day. T. Chuluunbaatar *et al.* (2023) studied the anatomical and histological characteristics of lymphoid tissue associated with the reproductive organs, specifically in the region of the vaginal vestibule, in healthy, non-pregnant, adult goats and pigs.

Secondary organs of the immune system in animals are recognised to include the spleen, lymph nodes, and haemolymph nodes (Ghosh & Stumhofer, 2021; Pan *et al.*, 2023; Cruz de Casas *et al.*, 2024). The spleen is a crucial component of the immune system, responsible for filtering blood to maintain immune homeostasis (Wei *et al.*, 2022). As noted by G. Crane *et al.* (2021), the unique morphological organisation of this organ facilitates a key role in the integration of the circulatory, reticuloendothelial, and immune systems. The organ filters ageing erythrocytes, immune complexes (antigen-antibody), apoptotic bodies, damaged cells, and other elements circulating within the blood. The histological structure of the spleen reflects its functional diversity and complexity. As a specialised lymphoid organ, the spleen plays a significant role in both innate and adaptive immune responses. Populations of innate immune cells, including B cells, natural killer cells (NK cells), and macrophages, are located within different functional zones of the organ (Aliyu *et al.*, 2021).

Lymph nodes are compact, highly organised structures of the secondary lymphoid organs, playing a key role in coordinating innate and adaptive immune responses to exogenous antigens, including vaccine components (Cakala-Jakimowicz *et al*., 2021). To perform this function, specialised zones are formed within the nodes, integrating blood and lymphatic vessels and facilitating the directed migration of immune cells. Specifically, according to L. Dubreil *et al.* (2022), B cells are directed to lymphoid follicles, where they undergo selection and maturation of clones producing high-affinity antibodies against antigens.

Haemolymph nodes are small, soft, dark red lymphoid organs found in mammals. They are typically located along the vertebral column, abdominal aorta, and within the perirenal adipose tissue, functioning as secondary organs of haematopoiesis and immunogenesis. They are involved in the destruction of aged erythrocytes, processes of erythropoiesis, erythrophagocytosis, and the activation of immune cells, thus contributing to the body's immune response (Arbaev *et al*., 2019). According to M. Yamada *et al.* (2025), haemolymph nodes represent a unique immune organ, distinct from conventional lymph nodes and the spleen.

Investigating the morphology of these organs in wild boars is significant for both fundamental science and the applied aspects of veterinary medicine and epidemiology. Such a study allows for assessing population health status, identifying the impact of environmental factors and pathogenic agents, and developing measures for animal conservation and the control of infectious diseases. Furthermore, analysis of the morphological features of these organs in wild boars provides insights into the state of their immune system and adaptation mechanisms in a changing environment. This study aimed to examine the morphological and functional characteristics of the lymphoid structures within the spleen, mesenteric lymph nodes, and haemolymph nodes in sexually mature individuals of the Asian wild boar subspecies.

Materials and Methods

The subject of this study was the Asian wild boar subspecies, inhabiting the mountainous steppe zone of the Moskva District, Chüy Region, Kyrgyz Republic. Research materials comprised the spleen, mesenteric lymph nodes, and haemolymph nodes, which were collected during post-mortem examination (necropsy). Biological material was obtained through the licensed harvesting of animals for scientific purposes, carried out under permission issued by the Department of Protection and Rational Use of Natural Resources of the State Agency for Environmental Protection and Forestry under the Government of the Kyrgyz Republic. The harvesting was conducted in the autumn of 2024, adhering to the principles of humane animal treatment (European Convention..., 1986) and following the Hunting Rules in the Territory of the Kyrgyz Republic (2003).

The study group consisted of three individuals: two males and one female. Animal age was determined based on age-related changes in the skull and dental system, following the methodology described by P. Kozlo (1973). The first boar was approximately four years of age, and the second was approximately five years of age. The age of the female corresponded to indicators characteristic of four-year-old individuals. The mass of the animal carcasses was not determined due to the absence of weighing procedures. Immediately after harvesting, a post-mortem examination of the animals was performed in the field, followed by a detailed pathological inspection of the organs, during which no macroscopically visible changes were observed. During the visual inspection, the syntopy, shape, colour, and consistency of the organs were assessed. For histological analysis, tissue samples were fixed directly on-site in a 10% aqueous solution of neutral buffered formalin for 24 hours.

Under laboratory conditions, standard histological processing of organ fragments was conducted, including dehydration, embedding in paraffin, and the preparation of paraffin blocks. Tissue samples, fixed in a 10% aqueous solution of neutral formalin, were initially washed in running water for 24 hours before being sequentially dehydrated in increasing concentrations of ethanol (50%, 60%, 70%, 80%, 90%, 96% I, and 96% II). Each dehydration step lasted for 24 hours. Residual ethanol was removed using chemically pure xylene over a period of three hours, after which the samples were infiltrated with paraffin. Finally, paraffin blocks were prepared and mounted onto wooden holders.

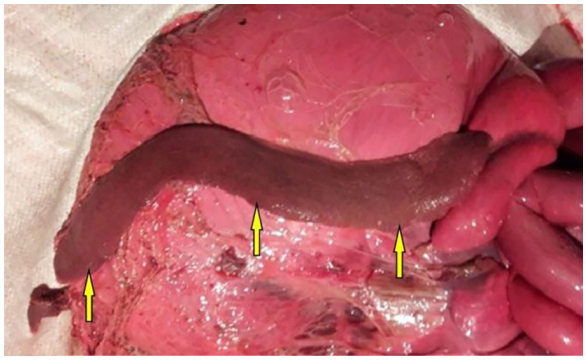
Serial sections, 4-5 μm thick, were cut from the paraffin blocks using a pfm Slide 4004M sledge microtome (Germany). Sections were floated onto a water bath heated to 37°C, then transferred to glass slides using a dissecting needle and subsequently dried on a specialised hot plate. Histological sections were stained with haematoxylin and eosin for general structural description and assessment of cellular composition, and Van Gieson's method was applied for the identification of muscular and connective tissue elements.

Microscopic examination of the histological sections was performed using a MicroOptix MX 100 binocular microscope (Austria), and imaging of tissue structures was carried out using a ToupCam UCMOS01300KPA camera (China), specifically designed for light microscopy. All aforementioned histological procedures were performed manually under standard conditions in the histological laboratory of the Department of Veterinary and Sanitary Expertise, Histology and Pathology at the Kyrgyz National Agrarian University named after K.I. Skryabin. The research was conducted in compliance with established methodological recommendations and requirements applicable to such investigations, following the methodology detailed in the guide by G. Merkulov (1969).

Results and Discussion

The study was conducted on the spleen, mesenteric lymph nodes, and haemolymph nodes of Asian wild boars (Fig. 1a). Upon external examination, all harvested animals were found to be in good body condition, possessing elastic skin, a dense undercoat, and a firmly attached hair coat. No macroscopically visible pathological changes were observed in the organs and tissues during necropsy. The anatomical investigation established that the wild boar spleen is an unpaired parenchymatous organ. It was situated in the left hypochondrium, adjacent to the greater curvature of the stomach. The dorsal pole of the spleen contacted the left kidney and partially the pancreas, while the ventral pole reached the umbilical region and bordered the liver. The parietal surface of the organ lay adjacent to the diaphragm, and the visceral surface featured a ridge through which the splenic hilus passed. The spleen exhibited an elastic consistency, a dark red colour, and an elongated, flattened shape with slightly rounded margins (Fig. 1b). These findings are consistent with the results of studies by E. Chirkova *et al.* (2023) investigated the location of the wild boar spleen. Furthermore, the syntopy of the wild boar spleen demonstrates similarity to the anatomical position of the pig spleen, as supported by data presented by H. Kaur (2019).

a



b

Figure 1. Asian wild boar subspecies after harvesting (a) and macroscopic appearance of the spleen (b), indicated by arrows

Source: authors' photo

Upon sectioning the spleen, the stroma and pulp were discernible. Small, greyish-white punctate formations were observed on the surface of the pulp. Microscopic examination revealed that the spleen of the Asian wild boar subspecies was encased in a dense connective tissue capsule, comprising a serous membrane. Large connective tissue trabeculae extended inwards from the capsule into the organ parenchyma, containing blood vessels – arteries and veins. Collagen fibres and a small number of smooth muscle cells were present within the capsule and trabeculae. Collagen fibres were distinctly evident in the capsule and trabeculae, and to a lesser extent around the walls of the blood vessels. Similar morphological features are described by N. Shringi *et al.* (2018) in their study of the spleen of the White Yorkshire pig (*Sus scrofa*), indicating structural similarity between the subspecies.

The organ parenchyma comprised white pulp and red pulp. The white pulp included lymphoid follicles and the periarterial lymphoid sheath, populated by corresponding populations of T and B cells, which defined them as the T and B zones, respectively. The T zone was represented by a diffuse infiltrate of T cells surrounding the central artery. The B zone consisted of lymphoid follicles situated adjacent to the T zone and containing B cells. Lymphoid follicles were characterised by the eccentric positioning of the central arteries. Findings from studies by B. Steiniger (2015) and R. Asaro & P. Cabrales (2021) confirm that the white pulp of the human spleen exhibits a similar organisation. Lymphoid follicles are located at varying distances from the commencement of the periarterial lymphoid sheath and are found both in the region where the artery branches from the trabecula and in its distal branching areas. However, according to L. da Fonseca Filho *et al.* (2023), the central artery within the white pulp of the brown-throated sloth spleen is centrally located within the germinal centres of the lymphoid follicles.

Lymphoid follicles within the spleen of the Asian wild boar subspecies displayed diverse shapes, including both round and oval forms. Functionally, they were categorised into three groups: newly formed follicles, resting follicles, and actively functioning follicles. Newly formed follicles were typically characterised by small size, indistinct boundaries, and a loose cellular structure (Fig. 2a). This appearance was attributed to their developmental stage and the absence of the morphological maturity characteristic of fully functional lymphoid structures. In contrast, resting lymphoid follicles (lacking a germinal centre) generally exhibited a round or oval shape, a compact arrangement of cells, and relatively small dimensions (Fig. 2b). However, these structures were observed relatively infrequently and in limited numbers within the spleen parenchyma of the Asian wild boar subspecies.

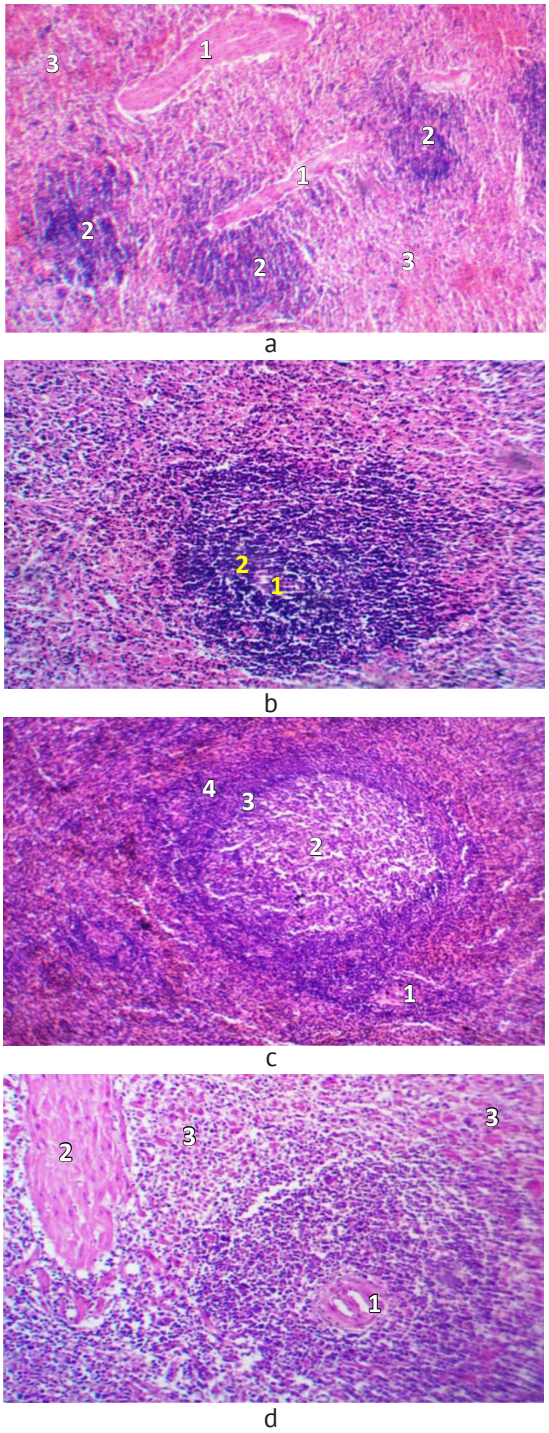


Figure 2. Microscopic appearance of the spleen parenchyma of the Asian wild boar subspecies (haematoxylin-eosin staining)

Note: a. Newly formed lymphoid follicles: 1 – trabeculae, 2 – white pulp, 3 – red pulp. Magnification x40. b. Resting lymphoid follicles: 1 – central artery, 2 – densely packed lymphocytes around the central artery. Magnification x100. c. Actively functioning lymphoid follicles: 1 – central artery, 2 – light (germinal) centre, 3 – mantle zone, 4 – marginal zone, 5 – red pulp. Magnification x100. d. Primary lymphoid follicles with loose cell arrangement: 1 – central artery, 2 – trabecula, 3 – red pulp. Magnification x100

Source: authors' photo

Within an actively functioning lymphoid follicle, a germinal centre was observed – a lighter region containing proliferating young cells – while the peripheral, darker portion comprised mature immunocompetent cells, including lymphocytes, monocytes, macrophages, and plasma cells. A well-defined marginal zone was distinctly evident, situated around the periphery of the follicle and enclosing the T and B zones. This zone served as a transitional area between the white and red pulp (Fig. 2c). According to R. Riedel *et al.* (2020) and G. Victora & M. Nussenzweig (2022), the formation of the lymphoid follicle germinal centre is contingent upon B cell activation in response to antigenic stimulation. Furthermore, the findings obtained by the authors of this article align with data from N. Fedorovskaya *et al.* (2020), who established that the functional activity of lymphoid follicles is determined by the developmental stage of their germinal centre. An increase in germinal centre size indicated an active phase of the immune response, whereas its decrease pointed to structural regression. Thus, the observed morphological features of the lymphoid follicles reflected the dynamics of the immune response and the degree of activation of splenic cellular elements contingent upon the nature of antigenic exposure.

The red pulp of the spleen was comprised of splenic sinuses and cords, containing a significant number of blood vessels. It was located between the capsule, trabeculae, and the lymphoid tissue of the white pulp. Its stroma was formed by reticular tissue, which included lymphocytes, macrophages, plasma cells, and erythrocytes. The morphological characteristics of the wild boar spleen's red pulp were consistent with data obtained in studies by R. Gnanadevi *et al.* (2019) investigating the spleen of sheep and goats, as well as H. Kaur (2019) studying the spleen of pigs.

Accumulations of lymphocytes, capable of forming new (primary) lymphoid follicles of the white pulp, were observed in certain areas of the red pulp (Fig. 2d). This finding was consistent with data presented by J. Kranich & N. Krautler (2016). Their study demonstrated that a significant portion of the red pulp lacks terminal capillaries and does not perform a filtering function. These areas consisted of aggregates of B and T cells, along with mononuclear phagocytes, at which sites lymphoid follicles could subsequently develop.

Based on the findings, the mesenteric lymph nodes of the Asian wild boar subspecies were determined to have an oval or elongated shape, a dense consistency, and a greyish-yellow colour. These nodes were arranged in a chain within the mesentery of the small intestine, between the loops of the colon, and in the short mesentery of the rectum (Fig. 3a). Microscopic examination revealed that the lymph nodes were externally enclosed by a well-developed connective tissue capsule. Wide trabeculae extended inwards from the well-developed capsule into the organ, forming a

branched structure within the cortical zone of the node. The internal framework of the lymph node was constituted by the stroma, which consisted of reticular connective tissue. The capsule and trabeculae comprised a dense network of collagen fibres, which were revealed as bright red structures when stained by Van Gieson's method (Fig. 3b). Collagen fibres were also present within the walls of blood vessels, albeit in limited quantities. Similar data were reported by A. Kalita *et al.* (2014), who indicated that the capsule and trabeculae of both the cortex and medulla of lymph nodes in Mizo local pig (Zo Vawk) primarily consisted of collagen fibres, with a lesser proportion of elastic fibres. The content of elastic fibres was notably higher in the blood vessels situated within the capsule and trabeculae. Furthermore, studies by Y. Bozkurt *et al.* (2019) demonstrated that the capsule and trabeculae of the wild boar lymph node were analogous to those of the domestic pig. They contained both collagen and elastic fibres and also included smooth muscle cells and fibroblasts.

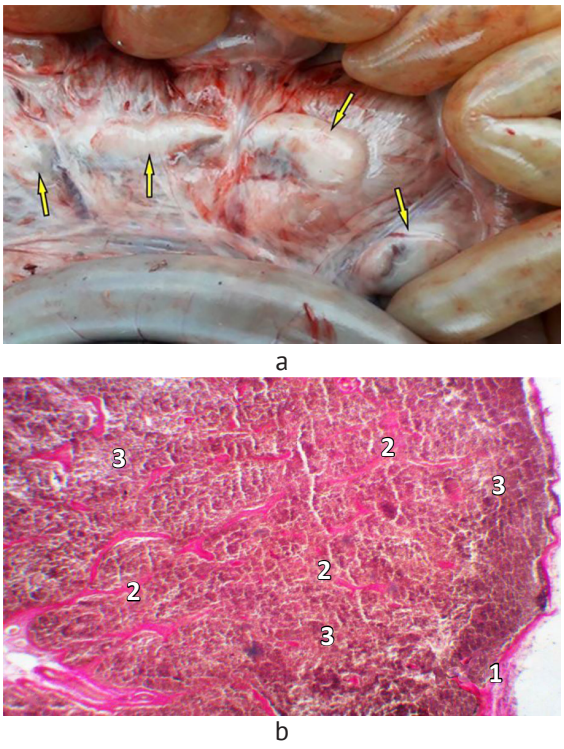


Figure 3. Macroscopic and microscopic appearance of the mesenteric lymph nodes of the Asian wild boar subspecies

Note: a. Mesenteric lymph nodes (indicated by arrows). b. Microscopic appearance of the lymph node cortex: 1 – organ capsule, 2 – branched trabeculae, 3 – organ parenchyma. Collagen fibres appear bright red in the capsule and trabeculae. Van Gieson's staining, magnification x40

Source: authors' photo

The organ parenchyma primarily comprised lymphocytes at various stages of maturation and functional activity. Within its structure, three main zones were discernible: the cortex, the paracortical region, and the medulla. The cortex was characterised by a high density of lymphocytes and was subdivided into the outer cortex and the paracortical zone. Lymphoid follicles were located in the outer cortex and were subdivided into primary (resting follicles) and secondary (actively functioning follicles). Secondary follicles predominated among them, distinguished by a distinctly evident light (germinal) centre, along with mantle and marginal zones. The germinal centre contained large lymphocytes (lymphoblasts) and was encircled by a layer of densely packed small (mature) lymphocytes (Fig. 4a). Similar morphological organisation has been noted in other animal species, including sheep (Rahmoun *et al.*, 2020) and camels (Fares *et al.*, 2023).

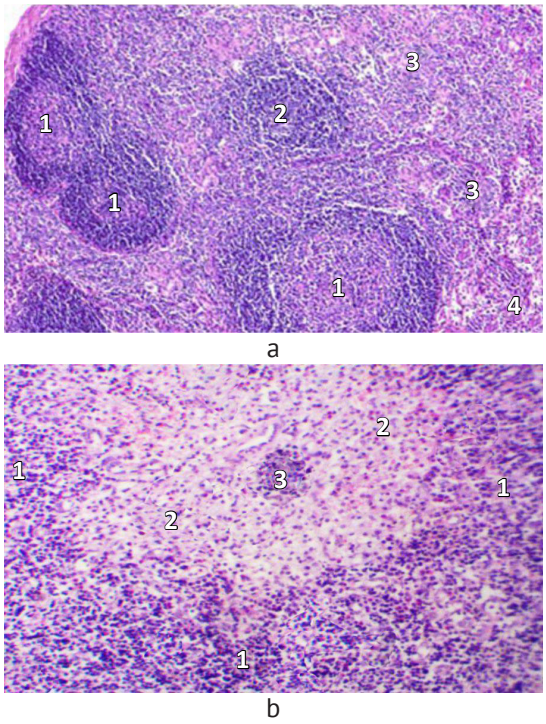


Figure 4. Microscopic appearance of the mesenteric lymph nodes of the Asian wild boar subspecies

Note: haematoxylin-eosin staining, magnification: a – x40, b – x100. a. Regions of the organ cortex: 1 – actively functioning lymphoid follicles, 2 – resting lymphoid follicles, 3 – paracortical zone, 4 – medulla. b. Region of the medulla surrounded by paracortical zones: 1 – paracortical zone, 2 – medulla, 3 – primary lymphoid follicle

Source: authors' photo

The paracortical zone of the lymph node was situated between the outer cortex and the medulla. It primarily consisted of diffusely distributed lymphocytes and surrounded both primary and secondary lymphoid follicles. In addition to lymphocytes, the cellular composition of the paracortical zone included dendritic cells and reticular fibroblasts. According to the study by G. Slack (2016), this region was considered the T zone of the lymph node, as it was predominated by mature

T cells, as well as varying numbers of large transformed immunoblasts, which could be either T or B cells. T cells, upon exposure to antigens, were activated, proliferated, and differentiated into effector cells or memory cells (Notarbartolo & Abrignani, 2022).

In the medulla, numerous reticular cells with associated reticular fibres were observed, interspersed with lymphocytes, plasma cells, and macrophages. Primary lymphoid follicles, lacking a distinctly defined separation zone, were identified in this region (Fig. 4b). Their number was significantly lower compared to the cortex. The cellular composition was predominantly represented by small lymphocytes, macrophages, and plasma cells. These findings were consistent with data presented by A. Panphilof *et al.* (2005), additionally noted that the main cell type in wild boar lymph nodes comprises lymphocytes, reticular cells are second in prevalence, and mast cells are present throughout all zones of the lymph node.

Haemolymph nodes identified in the wild boar were primarily located within the abdominal cavity along the abdominal aorta, in the perirenal adipose tissue, and deep within the omentum (Fig. 5a). They presented as formations of varying size, exhibiting a round-oval shape, ranging from dark red to brown in colour, with an elastic consistency. Similar haemolymph nodes have been described in humans (Pototskaya & Lapsar, 2016) and in the water deer (Artemeva, 2018). Upon sectioning, the parenchyma of the nodes was saturated with blood, while in certain areas, greyish-white inclusions and connective tissue strands were observed. Microscopic examination established that the haemolymph node was covered by a capsule consisting of fibrous connective tissue. Connective tissue trabeculae extended inwards from the capsule into the organ, dividing the parenchyma into separate regions. According to data from K. Arbaev *et al.* (2019), in the wild boar, the trabeculae in the haemolymph nodes not only possessed significant width but were also welldeveloped. A small number of smooth muscle cells and a significant quantity of collagen fibres were found in the capsule and trabeculae, which corresponded to data from T. Kannan *et al.* (2019).

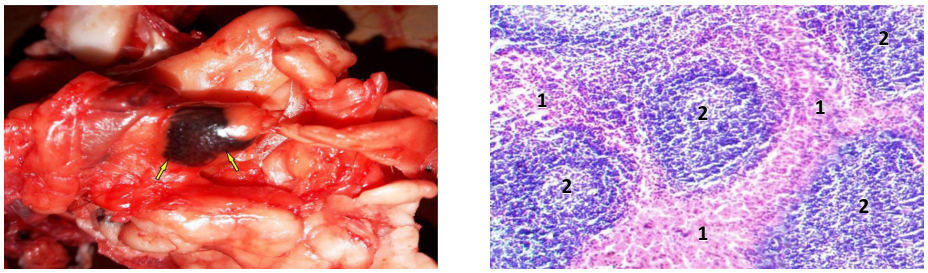


Figure 5. Macroscopic and microscopic appearance of the haemolymph node of the Asian wild boar subspecies
Note: a. Haemolymph nodes deep within the omentum (indicated by arrows). b. Microscopic appearance of the middle zone of the haemolymph node: 1 – accumulation of erythrocytes in the parenchyma, 2 – lymphoid follicles in different morphofunctional states. Magnification x200
Source: authors' photo

The organ parenchyma was subdivided into zones containing a mixture of blood and lymph, thus confirming the presence of haemolymph within the afferent vessels and sinuses. Beneath the capsule lay a wide subcapsular sinus, which was continuously connected to the trabecular sinuses. A significant number of erythrocytes were observed within the subcapsular sinus and peritrabecular spaces, imparting the node its characteristic red hue. According to studies by M. Zidan & R. Pabst (2004), haemolymph nodes contained subcapsular sinus, trabecular and medullary blood sinuses, indicative of their involvement in blood circulation and filtration. Accumulations of erythrocytes were observed throughout the entire parenchyma of the node, among which regions featuring a local concentration of lymphocytes were encountered. These lymphoid accumulations formed both follicles and diffusely distributed zones within the interfollicular space (Fig. 5b). Secondary lymphoid follicles, separated by blood sinuses, were predominantly observed. They were in an active functional state, evidenced by the presence of well-developed germinal centres. A mantle zone was identified around the periphery of the germinal centres. The cellular composition included small, medium, and large lymphocytes, macrophages, and plasma cells. These findings indicated that haemolymph nodes functioned as lymphoid organs. According to data from C. Park *et al.* (2001), haemolymph nodes likely perform functions related to haematopoiesis, blood filtration, and immune responses. However, the precise mechanisms underlying the functioning of this organ remain insufficiently studied (Boes & Durham, 2017). Consequently, the morphological characteristics of the secondary organs of immunogenesis presented in this study for the Asian wild boar subspecies serve as baseline data and reflect their functional activity in a healthy state.

Conclusions

Morphostructural analysis revealed that the spleen, mesenteric lymph nodes, and haemolymph nodes of

the Asian wild boar subspecies possess characteristic anatomical, histological, and cellular features. The spleen exhibits an organisation typical of a parenchymatous organ, with a clear demarcation between the white and red pulp. Its lymphoid follicles are present at various stages of maturation, indicative of active immune processes. The red pulp, comprised of reticular tissue and an extensive vascular network, confirms its role in blood filtration and the destruction of erythrocytes.

Mesenteric lymph nodes feature a well-developed capsule and trabeculae containing collagen fibres. Their structure includes distinct cortical and medullary zones, as well as a paracortical region containing diffuse lymphoid tissue. The predominance of secondary lymphoid follicles with germinal centres signifies active antigenic stimulation. Haemolymph nodes are characterised by a prominent sinusoidal system saturated with erythrocytes, indicating their involvement in blood filtration and the destruction of aged erythrocytes. The active state of lymphoid follicles further confirms their role in the immune response and haematopoiesis.

Further studies should encompass age-related and seasonal variations in the morphofunctional state of these organs, and include a comparative analysis with domestic pigs to elucidate evolutionary differences in immune system organisation. These findings are of importance for veterinary medicine, ecology, and animal husbandry, potentially contributing to the development of strategies for controlling infectious diseases in wild animal populations.

Acknowledgements

The authors express their sincere gratitude to the PhD in Agricultural Sciences, Associate Professor Orozbek Keneshovich Aidraliev, and the Department of Protection and Rational Use of Natural Resources of the State Agency for Environmental Protection and Forestry under the Government of the Kyrgyz Republic for providing the opportunity to collect experimental material from wild animals.

Funding

None.

Conflict of Interest

The authors declare that there is no conflict of interest in this study.

References

[1] Aliyu, M., Zohora, F., & Saboor-Yaraghi, A.A. (2021). Spleen in innate and adaptive immunity regulation. *AIMS Allergy and Immunology*, 5(1), 1-17. doi: 10.3934/Allergy.2021001.

[2] Arbaev, K.S., Aidraliev, O.K., Amirakulov, M.M., & Azhybekov, B.S. (2019). Comparative morphofunctional state of hemolymph nodes in wild artiodactyls. *Bulletin of Hunting Studies*, 16(3), 178-183.

[3] Artemeva, E. (2018). Histomorphology of haemolymph nodes of water deer (*Hydropotes inermis argyropus*): Novel study. *Basrah Journal of Veterinary Research*, 17, 314-325. doi: 10.33762/bvetr.2018.144960.

[4] Asaro, R.J., & Cabrales, P. (2021). Red blood cells: Tethering, vesiculation, and disease in micro-vascular flow. *Diagnostics*, 11(6), article number 971. doi: 10.3390/diagnostics11060971.

[5] Boes, K.M., & Durham, A.C. (2017). Bone marrow, blood cells, and the lymphoid/lymphatic system. In J.F. Zachary (Ed.), *Pathologic basis of veterinary disease* (pp. 724-804). Maryland Heights: Mosby. doi: 10.1016/B978-0-323-35775-3.00013-8.

[6] Bozkurt, Y.A., Ateþ, S., Kozlu, T., & Baþak, F. (2019). The architecture of the lymph nodes in the abdominal and thoracic cavities of wild boar. *Indian Journal of Animal Research*, 53(5), 609-615. doi: 10.18805/ijar.B-759.

[7] Cakala-Jakimowicz, M., Kolodziej-Wojnar, P., & Puzianowska-Kuznicka, M. (2021). Aging-related cellular, structural and functional changes in the lymph nodes: A significant component of immunosenescence? An overview. *Cells*, 10(11), article number 3148. doi: 10.3390/cells10113148.

[8] Chirkova, E.N., Zavaleeva, S.M., Sadykova, N.N., Avtaeva, E.N., & Sedegov, S.V. (2023). The boar heart and spleen anatomy (*Sus scrofa*). *Actual Questions of Veterinary Biology,* 2(58), 16-19. doi: 10.24412/2074-5036-2023-2-16-19.

[9] Chuluunbaatar, T., Ichii, O., Masum, M.A., Namba, T., & Kon, Y. (2023). Morphological characteristics of genital organ-associated lymphoid tissue in the vaginal vestibule of goats and pigs. *Veterinary Sciences*, 10(1), article number 51. doi: 10.3390/vetsci10010051.

[10] Crane, G.M., Liu, Y.C., & Chadburn, A. (2021). Spleen: Development, anatomy and reactive lymphoid proliferations. *Seminars in Diagnostic Pathology*, 38(2), 112-124. doi: 10.1053/j.semdp.2020.06.003.

[11] Cruz de Casas, P., Knöpper, K., Dey Sarkar, R., & Kastenmüller, W. (2024). Same yet different – how lymph node heterogeneity affects immune responses. *Nature Reviews Immunology*, 24(5), 358-374. doi: 10.1038/s41577-023-00965-8.

[12] Da Fonseca Filho, L.B., *et al.* (2023). Topographic and morphological aspects of the spleen of Bradypus variegatus (SCHINZ, 1825). *Medicina Veterinária*, 17(4), 210-216. doi: 10.26605/medvet-v17n4-5824.

[13] Dubreil, L., Ledevin, M., Hervet, C., Menard, D., Philippe, C., Michel, F.J., Larcher, T., Meurens, F., & Bertho, N. (2022). The internal conduit system of the swine inverted lymph node. *Frontiers in Immunology*, 13, article number 869384. doi: 10.3389/fimmu.2022.869384.

[14] European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes. (1986, March). Retrieved from https://rm.coe.int/168007a67b.
[15] Fares, M.A., Khenenou, T., Rahmoun, D.E., & Houari, H. (2023). Gross anatomical, histological, and cytological study of the one-humped camel (*Camelus dromedarius*) lymph nodes in southeastern Algeria. *Iranian Journal of Veterinary Medicine*, 17(4), 333-344. doi: 10.32598/IJVM.17.4.202301.
[16] Fedorovskaya, N.S., Zheleznov, L.M., Zaitsev, V.B., Diakonov, D.A., & Koledaeva, Ye.V. (2020). Morphometric characteristic of histoarchitectonics of the human spleen. *Morphology*, 157(1), 41-47. doi: 10.34922/AE.2020.157.1.007.
[17] Getmantseva, L.V., Traspov, A.A., Bakoev, N.F., Prytkov, Yu.A., Bakoev, S.Yu., Petrikeeva, L.V., & Kostyunina, O.V. (2020). Identification of "Selection signatures" in pigs and wild boars (review). *Agricultural Biology*, 55(2), 243-256. doi: 10.15389/agrobiology.2020.2.243rus.
[18] Ghosh, D., & Stumhofer, J.S. (2021). The spleen: "Epicenter" in malaria infection and immunity. *Journal of Leukocyte Biology*, 110(4), 753-769. doi: 10.1002/JLB.4RI1020-713R.
[19] Gnanadevi, R., Senthilkumar, S., Kannan, T.A., & Ramesh, G. (2019). Comparative histoarchitectural study of splenic components in sheep and goat. *International Journal of Current Microbiology and Applied Sciences*, 8(5), 1387-1394. doi: 10.20546/ijcmas.2019.805.158.
[20] Grigoryev, V.S., Khakimov, I.N., & Molyanova, G.V. (2023). Morphofunctional development of lymphoid hematopoiesis organs in pigs during the prenatal period. *Bulletin Samara State Agricultural Academy*, 8(2), 87-94. doi: 10.55170/19973225_2023_8_2_87.
[21] Hunting Rules in the Territory of the Kyrgyz Republic. (2003, February). Retrieved from https://faolex.fao.org/docs/pdf/kyr104375.pdf.
[22] Irgashev, A., Kalandarova, Z., Amirakulov, M., Yethindra, V., & Tagaev, T. (2020). Age-dependent alterations in gross appearance and histology of the conjunctiva-associated lymphoid tissue (CALT) in pigs. *Veterinary Practitioner*, 21(1), 38-41.
[23] Kalita, A., Kalita, P.C., & Doley, P.J. (2014). Light microscopic study on the peripheral lymphnodes of Mizo local pig (Zo Vawk). *Asian Journal of Biomedical and Pharmaceutical Sciences*, 4(28), 7-12.
[24] Kannan, T.A., Gnanadevi, R., Senthilkumar, S., & Ramesh, G. (2019). Histomorphometric and immunohistochemical details of hemal nodes in Indian buffalo. *Journal of Entomology and Zoology Studies*, 7(2), 384-387.
[25] Kaur, H. (2019). *Histomorphological and histochemical studies on pig spleen*. (Doctoral dissertation, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India).
[26] Kozlo, P.G. (1973). *Determination of age, selection, and capture of the wild boar*. Minsk: Uradzhaj.
[27] Kranich, J., & Krautler, N.J. (2016). How follicular dendritic cells shape the B-cell antigenome. *Frontiers in Immunology*, 7, article number 225. doi: 10.3389/fimmu.2016.00225.
[28] Lunney, J.K., van Goor, A., Walker, K.E., Hailstock, T., Franklin, J., & Dai, C. (2021). Importance of the pig as a human biomedical model. *Science Translational Medicine*, 13(621), article number eabd5758. doi: 10.1126/scitranslmed.abd5758.
[29] Markov, N., *et al.* (2022). The wild boar *Sus scrofa* in northern Eurasia: A review of range expansion history, current distribution, factors affecting the northern distributional limit, and management strategies. *Mammal Review*, 52(4), 519-537. doi: 10.1111/mam.12301.
[30] Marunchyn, A., Kovalova, A., Palys, M., Tereshchenko, K., & Honcharenko, M. (2024). Clinical and morphological analysis of splenic neoplasms. *Ukrainian Journal of Veterinary Sciences*, 15(3), 113-135. doi: 10.31548/veterinary3.2024.113.
[31] Merkulov, G.A. (1969). *Course in pathohistological techniques*. Leningrad: Medicina.
[32] National Statistical Committee of the Kyrgyz Republic. (n.d.). Retrieved from https://stat.gov.kg/ru/statistics/turizm-otdyh-ohrana-okruzhayushej-sredy/.
[33] Notarbartolo, S., & Abrignani, S. (2022). Human T lymphocytes at tumor sites. *Seminars in Immunopathology*, 44(6), 883-901. doi: 10.1007/s00281-022-00970-4.
[34] Pabst, R. (2020). The pig as a model for immunology research. *Cell and Tissue Research*, 380, 287-304. doi: 10.1007/s00441-020-03206-9.
[35] Pan, W.R., *et al.* (2023). Hemolymph node – an immunomorphlogical organ: Modeling the hemolymph node by allografting renal tissue in the rat. *Cells Tissues Organs*, 212(2), 147-154. doi: 10.1159/000520360.
[36] Panphilof, A.B., Vidyakina, M.A., & Sokolof, V.I. (2005). The cytoarchitectonics of the mesenteric lymphonodes of the wild pigs. *Morphological Newsletter*, 3-4, 76-79.
[37] Park, C.B., Seong, J.K., Lee, I.S., Lee, H.S., Lee, J.S., & Yoon, Y.S. (2001). Structure of hemolymph node in WKY rats. *Korean Journal of Veterinary Research*, 41(3), 287-292.
[38] Pototskaya, O.Y., & Lapsar, H.S. (2016). Subtypes of human atypical lymph nodes, defined based on comparative morphological analysis. *Morphologia*, 10(2), 45-52. doi: 10.26641/1997-9665.2016.2.45-52.

[39] Rahmoun, D.E., Barani, S., & Lieshchova, M.A. (2020). Anatomo-topographic and radiological study of the sheep lymph node in Algeria. *Journal of Veterinary Medicine and Research*, 7(4), article number 1195.
[40] Riedel, R., *et al*. (2020). Discrete populations of isotype-switched memory B lymphocytes are maintained in murine spleen and bone marrow. *Nature Communications*, 11(1), article number 2570. doi: 10.1038/s41467-020-16464-6.
[41] Shringi, N., Mathur, R., Kumar, V., Rohlan, K., & Ganguly, S. (2018). Histological studies on the spleen of large White Yorkshire Pig (*Sus scrofa*). *Journal of Entomology and Zoology Studies*, 6(1), 1142-1144. doi: 10.22271/j.ento.6.1.257.1.
[42] Slack, G.W. (2016). The pathology of reactive lymphadenopathies: A discussion of common reactive patterns and their malignant mimics. *Archives of Pathology & Laboratory Medicine*, 140(9), 881-892. doi: 10.5858/arpa.2015-0482-SA.
[43] Steiniger, B.S. (2015). Human spleen microanatomy: Why mice do not suffice. *Immunology*, 145(3), 334-346. doi: 10.1111/imm.12469.
[44] Victora, G.D., & Nussenzweig, M.C. (2022). Germinal centers. *Annual Review of Immunology*, 40(1), 413-442. doi: 10.1146/annurev-immunol-120419-022408.
[45] Wei, Y., Wang, T., Liao, L., Fan, X., Chang, L., & Hashimoto, K. (2022). Brain-spleen axis in health and diseases: A review and future perspective. *Brain Research Bulletin*, 182, 130-140. doi: 10.1016/j.brainresbull.2022.02.008.
[46] Yamada, M., Aizawa, E., Dohi, A., Sasaguri, K., Yamamoto, T., & Noguchi, T. (2025). Rat hemolymph nodes provide a direct communication site for macrophages interacting with erythrocytes and mast cells. *Cells Tissues Organs*, ahead of print. doi: 10.1159/000543747.
[47] Zidan, M., & Pabst, R. (2004). Histological, histochemical and immunohistochemical study of the haemal nodes of the dromedary camel. *Anatomia, Histologia, Embryologia*, 33(5), 284-289. doi: 10.1111/j.1439-0264.2004.00550.x.

Жапайы камандардагы иммуногенездин экинчилик органдарынын морфоструктуралык мүнөздөмөсү

Марасулбек Амиракулов

Биология илимдеринин кандидаты, доцент
К.И. Скрябин атындагы Кыргыз улуттук агрардык университети
720005, Медеров көч., 68, Бишкек ш., Кыргыз Республикасы
https://orcid.org/0000-0002-2432-4670

Кубан Арбаев

Ветеринария илимдеринин доктору, профессор
К.И. Скрябин атындагы Кыргыз улуттук агрардык университети
720005, Медеров көч., 68, Бишкек ш., Кыргыз Республикасы
https://orcid.org/0000-0003-3910-5283

Бактыбек Ажыбеков

Ветеринария илимдеринин кандидаты, доцент
К.И. Скрябин атындагы Кыргыз улуттук агрардык университети
720005, Медеров көч., 68, Бишкек ш., Кыргыз Республикасы
https://orcid.org/0000-0002-7079-6791

Людмила Лыхина

Ветеринария илимдеринин кандидаты, доцент
К.И. Скрябин атындагы Кыргыз улуттук агрардык университети
720005, Медеров көч., 68, Бишкек ш., Кыргыз Республикасы
https://orcid.org/0000-0002-9371-8278

Расида Карабаева

Ветеринария илимдеринин кандидаты, доцент
К.И. Скрябин атындагы Кыргыз улуттук агрардык университети
720005, Медеров көч., 68, Бишкек ш., Кыргыз Республикасы
https://orcid.org/0000-0001-5845-8020

Аннотация. Ар кандай этиологиядагы ылардардын патогенезинде иммундук клеткалардын катышуусун талдоо жана аны дарылоо жана алдын алуу иштеринде колдонуу үчүн иммундук системанын органдарынын жана ткандарынын нормадагы морфологиясын билүү зарыл. Бул иште, Кыргыз Республикасынын Чүй облусунун Москва районунун тоо-талаа аймактарын жердеген азиялык түрчөдөгү жапайы камандардын (*Sus scrofa nigripes*) экинчилик (четки) иммундук органдарынын морфологиялык изилдөөлөрүнүн жыйынтыктары берилген. Изилдөөнүн максаты болуп дени сак жаныбарлардын көк боорунун, мезентериалдык лимфа түйүндөрүнүн жана гемолимфа түйүндөрүнүн лимфоиддик түзүмдөрүнүн жалпы морфологиялык жана функциялык өзгөчөлүктөрүн аныктап көрсөтүү саналат. Изилдөөнүн материалы жыныстык жактан жетилген үч баш жапайы камандан алынган. Коюлган максатка жетүү үчүн анатомиялык жана гистологиялык изилдөө ыкмалары пайдаланылган. Анатомиялык ыкмалар аркылуу органдардын синтопиясы, формасы, түсү жана консистенциясы аныкталган. Гистологиялык изилдөөлөр жалпы кабыл алынган ыкмалар боюнча жүргүзүлгөн: органдын жалпы түзүмдүк уюмдуулугун аныктоо үчүн гематоксилин жана эозин боёктору, ал эми булчуң жана тутумдаштыргыч ткандын элементтерин айырмалоо үчүн Ван-Гизон ыкмасы колдонулган. Жарык микроскобунун жардамында органдардын стромалык жана паренхималык түзүмдөрү, клеткалык курамы жана лимфоиддик пайда болуулардын морфофункциялык абалдары талданган. Изилдөөлөрдүн жыйынтыгында жыныстык жактан жетилген азиялык түрчөдөгү жапайы камандардын көк боорунун, лимфа жана гемолимфа түйүндөрүнүн морфологиялык өзгөчөлүктөрү жана морфофункциялык абалы аныкталды. Азиялык түрчөдөгү жапайы камандардын иммундук системасынын экинчилик органдары боюнча алынган маалыматтар морфологиялык норманы өзүнө камтыйт. Жыйынтыктар, жапайы камандардын органдары менен ткандарынын нормадагы жана патологиялык абалдардагы морфологиясы жана иммунологиясы боюнча мындан аркы эксперименталдык жана колдонмо мүнөздөгү иштерди жүргүзүү үчүн нормативдик негиз катары сунушталат. Ошондой эле бакма жана жапайы жаныбарлардын органдарынын функциялык, экологиялык жана салыштырмалуу морфологиясы боюнча алектенген биологдордун жана ветеринардык дарыгерлердин илимий жана практикалык ишмердүүлүгүндө колдонулушу мүмкүн

Негизги сөздөр: көк боор; лимфа түйүндөрү; гемолимфа түйүндөрү; трабекулалар; органдын паренхимасы; лимфоиддик фолликулдар; лимфоциттер

Морфоструктурная характеристика вторичных органов иммуногенеза у диких кабанов

Марасулбек Амиракулов

Кандидат биологических наук, доцент
Кыргызский национальный аграрный университет им. К.И. Скрябина
720005, ул. Медерова, 68, г. Бишкек, Кыргызская Республика
https://orcid.org/0000-0002-2432-4670

Кубан Арбаев

Доктор ветеринарных наук, профессор
Кыргызский национальный аграрный университет им. К.И. Скрябина
720005, ул. Медерова, 68, г. Бишкек, Кыргызская Республика
https://orcid.org/0000-0003-3910-5283

Бактыбек Ажыбеков

Кандидат ветеринарных наук, доцент
Кыргызский национальный аграрный университет им. К.И. Скрябина
720005, ул. Медерова, 68, г. Бишкек, Кыргызская Республика
https://orcid.org/0000-0002-7079-6791

Людмила Лыхина

Кандидат ветеринарных наук, доцент
Кыргызский национальный аграрный университет им. К.И. Скрябина
720005, ул. Медерова, 68, г. Бишкек, Кыргызская Республика
https://orcid.org/0000-0002-9371-8278

Расида Карабаева

Кандидат ветеринарных наук, доцент
Кыргызский национальный аграрный университет им. К.И. Скрябина
720005, ул. Медерова, 68, г. Бишкек, Кыргызская Республика
https://orcid.org/0000-0001-5845-8020

Аннотация. Чтобы проанализировать участие иммунных клеток в патогенезе болезней различной этиологии и использовать в лечебных и профилактических работах, необходимо знать нормальную морфологию органов и тканей иммунной системы. В данной работе представлены результаты морфологического исследования вторичных (периферических) органов иммунной системы дикого кабана азиатского подвида (*Sus scrofa nigripes*), обитающих в горностепной местности Московского района Чуйской области Кыргызской Республики. Целью исследования было выявление общих морфологических и функциональных особенностей лимфоидных структур селезенки, мезентериальных лимфатических узлов и гемолимфатических узлов у здоровых животных. Материалы исследования были отобраны от трех голов половозрелых диких кабанов. Для достижения поставленной цели использованы анатомические и гистологические методы исследований. Анатомическими методами были определены синтопия, форма, цвет и консистенция данных органов. Гистологические исследования проводили по общепринятым методикам: для выяснения общей структурной организации органа окрашивали гематоксилином и эозином, а для дифференцировки мышечных и соединительнотканных элементов использовали метод Ван-Гизона. С помощью светового микроскопа анализировали стромальную и паренхиматозную структуру, клеточный состав и морфофункциональное состояние лимфоидных образований. В результате исследований были установлены морфофункциональное состояние и морфологические особенности селезенки, лимфатических и гемолимфатических узлов у дикого кабана азиатского подвида в половозрелой стадии. Полученные данные о вторичных органах иммунной системы кабана азиатского подвида представляют собой морфологическую норму. Результаты могут быть рекомендованы как нормативная основа для дальнейших экспериментальных и прикладных разработок морфологии, иммунологии органов и тканей диких кабанов в норме и при патологических состояниях. Также будут использованы в исследованиях и практической работе ветеринарных врачей и биологов, занимающихся функциональной, экологической и сравнительной морфологией органов домашних и диких животных

Ключевые слова: селезенка; лимфатические узлы; гемолимфатические узлы; трабекулы; паренхима органа; лимфоидные фолликулы; лимфоциты