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RESEARCH ARTICLE

A GENERAL OVERVIEW OF POULTRY HISTOLOGY

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ABSTRACT

Poultry are domesticated birds raised by humans for their eggs, meat, or feathers. The domestication of birds occurred several thousand years ago. This likely began as a result of humans collecting eggs from wild birds and raising the hatchlings, but eventually led to the practice of keeping these birds in captivity permanently. Selective breeding for traits such as rapid growth, egg-laying ability, conformation, feather quality, and temperament has occurred over centuries, resulting in modern breeds that often look very different from their wild ancestors. While some birds are still kept in small flocks within extensive systems, most of the poultry available on the market today are raised in intensive commercial operations. This review provides the histological features of poultry and a brief summary of studies conducted on poultry histology.

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INTRODUCTION

Bird anatomy, or the physiological structure of birds' bodies, shows many unique adaptations that mostly aid in flight. Birds have a lightweight skeletal system and light but strong muscles, and these, along with circulatory and respiratory systems with very high metabolic rates and oxygen supply, allow the bird to fly.

Eye lens (Lens): The lens consists of lens capsule, subcapsular epithelium and lens body. The lens does not contain blood vessels and nerve fibers (Tekelioğlu, 2002). The lens capsule is a slightly thickened basement membrane on the anterior surface. Subcapsular epithelial cells (anterior lens cells) show high mitotic activity. These cells cover only the anterior "hemisphere" of the lens in adults. Subcapsular epithelial cells change shape at the equatorial part of the lens, lengthen and transform into lens fibrils. The lens body consists mainly of lens fibrils. Lens fibrils are very long (up to 12 mm) hexagonal cells. They are located just below the subcapsular epithelial cells. Older lens fibrils lose their nuclei. Lens fibrils are tightly bound together. They contain crystalline proteins in their cytoplasm. These proteins provide the lens with properties such as transparency and light refraction (Junqueira *et al*, 1995).

Poultry lenses are histologically distinguished from mammalian lenses by a circular pad around the center of the lens (Jones *et al*, 2007). This equatorial circular pad formed by modified lens fibers can be very important. There is a space between the center and the circular pad and it is filled with fluid (Kern, 2007; Ross and Pawlina, 2006). The posterior surface of the lens is flat or less curved, while the anterior surface is soft, flexible, transparent and biconvex (Kern, 2007). The primary function of the poultry lens is to send light to the retina, where the image is formed together with the cornea (Jones *et al*, 2007; Samuelson, 2007). The water content of the lens is 65% and the protein content is 35%. Dehydration and sodium-potassium transitions in the lens are carried out by the active sodium-potassium adenosine triphosphate pump in the subcapsular epithelial cells (Jones *et al*, 2007; Wheater *et al*, 1987). Diurnal bird species have a flatter lens surface compared to aquatic and nocturnal species. The lens capsule of poultry contains type IV collagen fibers (Jones *et al*. 2007). Kuloğlu (2016) reported that in the partridge (*Alectoris chukar*), the lens is surrounded by an outer capsule, with subcapsular epithelial cells just below this capsule and lens fibrils under the epithelial cells (Kuloğlu, 2016). Kuloğlu (2022) reported that the lens capsule contains acidic and neutral mucins in histochemical staining of the lens in the partridge.

She reported that the presence of acidic and neutral mucins may be effective in protecting the lens capsule against pathogens (Kuloğlu, 2022).

Conjunctiva: The conjunctiva, which develops from the ectoderm together with the eyelids in seven weeks, is a thin and transparent mucous membrane. It covers the posterior surface of the eyelids and the anterior surface of the sclera. It continues with the eyelid skin at the mucocutaneous junction at the lid margin and with the corneal epithelium at the limbus (Özer, 2010). The conjunctiva is a thin, transparent membrane that covers the part of the eye up to the cornea and the inner surface of the eyelids. This membrane prevents the eyelids from damaging the eyeball during movement and keeps the inner part of the eye separate from the external environment. It also acts as a physical barrier, preventing dust, foreign bodies, and microorganisms from reaching the deeper parts of the eye and causing inflammation (Akgöz, 2006). The conjunctiva not only contributes to the secretion of the tear film but also plays a role in immunological defense reactions and has the ability to resorb (Kocamış, 2005). The conjunctiva consists of two layers: epithelium and stroma (lamina propria). Goblet cells that secrete abundant mucin are present in the epithelium (Özer, 2010). The structures called microvilli and micropil on the surface of the epithelium are covered with glycocalyx and a hydrophilic mucin layer (Kocamış, 2005). Mucins are high molecular weight glycoproteins that constitute the major component of the mucus layer and are formed by the addition of predominantly oglycans and limited amounts of N-glycans to a central peptide core (Carlstedt, 1985) and are produced by many epithelial tissues in vertebrates (Carlstedt *et al*. 1985; Öztabak, 2005). Mucin secreted from goblet cells that intercalate between the microvilli in the corneal epithelium provides surface smoothness and, due to its high water-holding capacity, ensures that tears remain in the cornea (Kocamış, 2005; Reece, 2009). Goblet cells also contain high levels of lysozyme to digest bacterial cell walls. Lysozyme is found in most animal tissues and secretions. However, it is found in much higher concentrations in leukocytes, nasal secretions and tears (Reece, 2009).

Light microscopically, the conjunctiva consists of nonlymphoid and lymphoid regions (Aştı *et al*, 2000). Nonlymphoid conjunctiva consists of 2-5 layers of stratified squamous epithelium containing goblet cells (Aştı *et al*, 2000; O'Sullivan *et al*, 2004). Kuloğlu (2018) reported that numerous goblet cells and stratified squamous epithelium were observed in the nonlymphoid conjunctiva of the chukar partridge *(Alectoris chukar)*. The conjunctiva is divided into four sections: palpebral conjunctiva, fornix, bulbar conjunctiva and plica seminularis. The palpebral conjunctiva consists of marginal, tarsal and orbital sections and covers the inner surface of the eyelids. The marginal conjunctiva has a multilayered but nonkeratinized epithelium similar to the skin. The tarsal conjunctiva is very tightly connected to the tarsa under it. The epithelial cells here are cylindrical. Vascularization is quite dense in the tarsal conjunctiva. It continues under the orbital conjunctiva. There are papillary formations on its surface (Özer, 2010). Kuloğlu (2018) reported that papillary formations were observed on the surface of the partridge orbital conjunctiva. In a study conducted on guinea pigs (Gasser *et al*., 2011), it was reported that PAS positive reaction was observed in conjunctival goblet cells without any regional distinction. Kuloğlu (2018) stated that no reaction was observed in the marginal region surface epithelium with the PAS staining method, and that tarsal and orbital region goblet cells showed reactions at different intensities. In studies conducted on rats (Sprague-Dawley) (Huang *et al*., 1988) and humans (Shatos *et al*., 2003), it was noted that conjunctival goblet cells contain both neutral and acidic mucins in similar proportions. Kuloğlu (2018) stated that the goblet cells in the tarsal and orbital regions of the chukar partridge (*Alectoris chukar*) also contain both neutral and acidic mucins. Furthermore, it was indicated that a small number of goblet cells in the chukar partridge contain only neutral or carboxylated mucins (Kuloğlu, 2018). Kuloğlu (2018) reported that in the PAS/AB pH 2.5 application, unlike the AB (pH 2.5) application, PAS positive dominance was observed in the mucins present in the majority of the goblet cells in the tarsal and orbital regions of the chukar partridge (*Alectoris chukar*).

CALT (Conjunctiva Associated Lymphoid Tissue): Potential pathogens and harmful substances constantly threaten the conjunctiva of the eye. Effective defense mechanisms are required to protect the structural and functional integrity of such delicate tissues. The most important component of these mechanisms is mucosa-associated lymphoid tissue (MALT), which is found in almost all mucosal regions of the body. Mucosa-associated lymphoid tissues (MALT) are structures that are localized in different tissues and in which specific response and/or tolerance against the antigens in the mucosa occur, and they differ from lymphocyte infiltrations with some characteristic features such as "high endothelial venules" (HEV) (Kelsall, 2004). Aggregated and solitary lymph follicles in MALT have germinal center, dome, corona and interfollicular regions. The close association of these follicles with the epithelium is important for an actively working MALT (Liebler-Tenorio & Pabst, 2006).

Recent studies have shown that MALT consists of specialized local stimulating regions (Organized-mucosa associated lymphoid tissues, O-MALT) and diffuse effector regions (Diffuse-mucosa associated lymphoid tissues, D-MALT) (Hannant, 2002; Knop & Knop, 2003; Liebler-Tenorio & Pabst, 2006; Russell *et al*., 2000). It is reported that O-MALT is typically localized to critical antigen entry sites such as the digestive and respiratory systems. Following the uptake and presentation of antigens, memory cells formed as a result of the local immune response in O-MALT go to D-MALT in other mucous membranes through the blood and settle (Elson, 1997; Gebert *et al*., 1996; Knop & Knop, 2003; Liebler-Tenorio & Pabst, 2006). Cell traffic between different mucous membranes depends on the specific migration of these cells between tissues, which is thanks to special vessels (HEVs) with high endothelial cells located in the interfollicular areas and at the bottom of the follicles (Cain & Phillips, 2008; Franklin & Remus, 1984; Knop & Knop, 2005). In this way, a common mucosal immune reaction is formed (Elson, 1997).

Some researchers (Astley & Chodosh, 2005; Bayraktaroğlu & Aştı, 2009; Fix & Arp 1989; Fix & Arp, 1991) have reported that conjunctiva-associated lymphoid tissue is similar in terms of location, epithelial and vascular properties to intestinal and bronchial-associated lymphoid tissues, where MALT is considered organized. CALT is lymphoid tissues located at different densities in different parts of the conjunctiva according to animal species. It is stated that factors such as healthy eye, age and individual differences may be effective in the number and distribution of conjunctival lymph follicles

(Guiliano *et al*., 2002). CALT consists of solitary and aggregated lymph follicles and FAE (Follicle-associated epithelium) that cover these follicles, does not contain goblet cells and also contains specialized membranous epithelial cells (M cells, M cells) for the uptake of antigens (Aştı *et al*., 2000a; 2000b; Liebler-Tenorio & Pabst, 2006; Kuloğlu, 2019). CALT plays an important role both in responding to diseases that may occur in the eye and in the recognition of some diseases (such as corneal transplant rejection, ocular allergy, dry eye disease) (Knop & Knop, 2005). CALT, which plays an important role in the ocular immune system, must have some characteristic features in order to be considered as a part of MALT. Accordingly, solitary and/or aggregated lymph follicles should form the lymphoid tissue, and these follicles should contain the dome, germinal center, corona and interfollicular areas, and also FAE, including M cells, should cover the follicles (Bayraktaroğlu & Aştı, 2009, Liebler-Tenorio & Pabst, 2006). Kuloğlu (2022), it was determined that conjunctival lymph follicles in chukar partridge (*Alectoris chukar*) were separated from lymphocyte infiltrations with the complete formation of cellular organization and typically had MALT characteristics.

The location of conjunctival lymph follicles differs between species. They are reported to be located in the palpebral conjunctiva in cattle, sheep and pigs (Chodosh *et al*., 1998), in palpebra nictitans in dogs (Guiliano *et al*., 2002) and mice (Sakimoto *et al*., 2002), in areas close to the lacrimal punctum in the nasal angle of the lower conjunctiva in rabbits (Franklin & Remus, 1984; Knop & Knop, 2005), in the nasal angle in turkeys (Fix & Arp, 1989). The appearance of lymph follicles at the macroscopic level may also differ between species. For example, in humans, lymph follicles are disc-shaped, whereas in rabbits, monkeys and other species, they are round (Knop & Knop, 2000). CALT follicles were observed to be clustered around the nasal region in chukar partridge (*Alectoris chukar*). Considering the standing position, the increase in the number of lymph follicles towards the nasal angle can be associated with the accumulation of tears here (Kuloğlu, 2022).

In studies, CALT has been described in human (Knop & Knop, 2000; Wotherspoon *et al*., 1994), rabbit (Franklin & Remus, 1984; Knop & Knop, 2005), guinea pig (Latkovic, 1989), mouse (Sakimoto *et al*., 2002), chicken (Fix & Arp, 1991), turkey (Fix & Arp, 1989), sheep (Chodosh *et al*., 1998; Liebler-Tenorio & Pabst, 2006), goat (Aştı *et al*., 2000a; 2000b), cattle (Bayraktaroğlu & Aştı, 2009), camel (Sandıkçı *et al*., 2005), pig (Chodosh *et al*., 1998), monkey (Ruskell, 1995), baboon (Astley *et al*., 2003). CALT in the rabbit consists of solitary and/or aggregated lymph follicles. It is reported that these follicles are covered by a single layer of squamous epithelium that does not contain goblet cells (Franklin & Remus, 1984; Knop & Knop, 2005). Kuloğlu (2022), it was determined that CALT in chukar partridge (*Alectoris chukar*) was similar to the above-mentioned features. Studies have shown that the conjunctiva consists of non-lymphoid and lymphoid regions in light microscopic examination. While the nonlymphoid conjunctiva consists of 2-5 rows of stratified squamous epithelium containing goblet cells (O'Sullivan *et al*., 2004), the lymphoid region is reported to consist of solitary or aggregated lymph follicles and specialized FAE without goblet cells that cover these follicles (Aştı *et al*., 2000b; Knop & Knop, 2003). In CALT, as in MALT lymph follicles, there are germinal center, corona, interfollicular regions and subepithelial dome region (Chodosh & Kennedy, 2002). The findings obtained Kuloğlu (2022), are similar to CALTs identified in other species.

The transfer of the resulting immune response to MALT structures in other mucous membranes is due to HEVs (High Endothelial Venule) located in interfollicular areas and playing a role in the specific migration of lymphocytes between tissues (Cain & Phillips, 2008; Franklin & Remus, 1984; Knop & Knop, 2003). Kuloğlu (2022), HEVs (High Endothelial Venule) were found in the interfollicular areas of CALT in chukar partridge (*Alectoris chukar*) and at the bottom of the follicles.

Pecten Oculi: The anatomy of pecten oculi is specific to the bird's eye and is highly pigmented and vascular. Located at the end of the optic nerve, it connects the retina to the vitreous tissues (Dayan and Özaydın, 2013; Aydemir and Kuloğlu). In all vertebrates, the outer retina which includes the retinal epithelium (RPE) and photoreceptors (rods and cones) is supplied by the large fenestrated capillaries of the choriocapillaris. In most vertebrates a second vascular system nourishes the inner retina which includes all layers vitreadto the photoreceptors. This other vascular supply which is termed a supplemental nutritive device (SND) (Walls1942) or supplementary retinal circulation (Rodieck 1973)can take several forms, but in avian species it is representedas the pecten oculi. The pecten oculi in the avian is an interesting structure that defies functional analyses, despite the fact that it has been studied for over 300 years (Brach 1977). In avian, pecten oculi has a very vascular and pigmented structure (Kiama *et al* 1994,Gultiken *et al* 2012). It is located at the head of the optic nerve and extends from the retina towards the vitreous part (Braekevelt 1988, Orhan *et al* 2011). The size of the pecten oculi depends on the visual needs of the bird. Thus while birds active in the daytime have a large and highly complex pecten oculi with many folds; birds active at night have a relatively small and simple pecten oculi (Meyer 1977).
Histological features of the pecten oculi in all birds are very similar. It is composed of a thinly pleated plexus consisting of very large capillary vessels assembled by a sparse matrix of pigmented stromal cells. In most birds, the pecten apex is held together by a densely pigmented, fibrous 'bridge' of tissue which has a reduced vascularization with respect to the pecten pleats. The pecten oculi is attached basally to the optic nerve head and distally to the vitreous body by fine strands of vitreous tissue which interdigitates with processes of the bridge cells (Brach 1977). In the avian, retina is thicker than mammals and retinal blood vessels are absent (Pettigrew 1990). Therefore, it is suggested that the avascular retina of the pecten oculi basic function is feeding(Kiama *et al* 1994).One of the functions of the pecten oculi is the formation of the blood retinal barrier (Wolburg 1999). The endothelia of the pectineal capillaries are continuous, possessing elaborate tight junctions. Also two barrier-specific proteins, that is, the HT7-antigen and the glucose transporter isoform GluT-1, are expressed by the endothelial cells (Gerhardt 1996).

The pecten oculi is found in the vitreous chamber of the eye of all avians (Rochon- Duvigneaud 1943) and it is considered an indirect retinal trophic system (Michaelson1954, Puzzolo 1994), more effectively functioning during saccadic oscillations (Pettigrew *et al* 1990). It is composed of three different parts: the base, optic nerve head andthe folds. Kuloğlu and Boydak (2019) reported that the partridge pecten oculi consists of three different parts. The base plays a relevant mechanic role, as it providesstrong insertion of the pecten on the adjacent ocular layers along a zigzag line (Puzzolo *et al* 1985). This arrangement seems to be more functional than a rectilinear one in increasing its mechanical stability and its ability to withstand the inertial forces of the adjacent vitreous body (Tucker 1975). Furthermore, it represents the site where the larger vessels (arterioles and venules) are found (Hossler and Olson 1984). In the budgerigar these vessels are placed along the basal part, close to the optic nerve fibers (Kiama *et al* 1994, Braekevelt 1998,Rahman *et al* 2010), is composed only by capillaries. In this study, chukar partridge of pecten oculi was observed to have blood vessels of different sizes. Kuloğlu and Boydak (2019) reported that the pecten oculi of the partridge have blood vessels of different sizes.

As to the folds, a relationship was proposed between the number of the pleats and the circadian activity and/ or the visual requirements of the single species (Braekevelt, 1998). In fact, a large and complicated pecten with 15–20 pleats is generally observed in photically active and visually oriented avians, whereas a pecten provided of smaller size and 4–5 pleats is found in avians with crepuscular or nocturnal habits and with reduced visual acuity. The location of the pecten oculi in *Alectoris chukar* used in this study conformed to that reported in other bird species. We observed that *Alectoris chukar* had a pleated-type pecten oculi which displayed folded structure. Kuloğlu and Boydak (2019) reported that the partridge has a serpentine type pecten oculi, which is consistent with the location reported in other bird species and exhibits a serpentine structure. In the researches showed that in other diurnal species such as in malard pecten oculi has 12-14 (Braekevelt 1990), great blue heron has 14-15 (Braekevelt 1991), emu has 3-4 (Braekevelt 1993), American crow has 22-25 (Braekevelt 1994), Australian galah has 20-25 (Braekevelt 1996),black kite has 12-13 (Kiama *et al* 1994, Kiama *et al* 2001), domestic poultry has 16-18 (Kiama *et al* 2001), jungle crow has 24-25 (Rahman *et al* 2010), quail has 19 (Orhan *et al* 2011), common buzzard has 17-18 (Gultiken *et al* 2012), budgerigar has 10-12 (Micali *et al* 2012),duck has 12, pigeon has 13-14, turkey has 21-22, starling has 17 (Dayan and Ozaydin 2013), stork has 15-17 (Onuk *et al* 2013) and partridge has 13-14 (Kuloğlu and Boydak, 2019) folds. However, nocturnal birds have small pectens such as nighthawk that has 4-5 (Braekevelt 1984),barred owl that has 8–10 (Smith *et al* 1996) and spotted eagle owl that has 5-6 (Kiama *et al* 2001) folds.

Although the functional morphology of pecten oculi is related to the life style of the avian (Kiama *et al* 2001), previous studies (Kiama *et al* 2006; Kuloğlu and Boydak, 2019) show that pecten oculi mainly consists of numerous capillaries, large blood vessels and pigment cells in various avian species. The capillaries are surrounded by thick basal membrane in pecten oculi of all investigated species in partridge as described in pervious study (Braekevelt 1988,Braekevelt 1990,Braekevelt 1994, Braekevelt 1996,Dayan and Ozaydın 2013, Kuloğlu and Boydak, 2019). It has been suggested that the thickened basal layer may support fragile endothelial cells with very thin cell bodies and numerous microfolds (Braekevelt 1988,Braekevelt 1996). The close relationship between pigment cells and capillary vessels has been reportedin the black kite (Kiama *et al* 2001), ostrich (Kiama *et al* 2006), and jungle crow (Rahman *et al* 2010), quail (Orhan *et al* 2011), storks (Onuk *et al* 2013), duck, pigeon, turkey, and starling (Dayan and Ozaydin 2013), partridge (*Alectoris chukar*) (Kuloğlu and Boydak, 2019). It has suggested that pigmented cells provide the structural reinforcement to pecten oculi for keeping it firmly erectile within the gel-like vitreous and also protect the blood vessels against damage from ultraviolet light (Braekevelt 1988, Kiama *et al* 1994,Braekevelt 1996). Kuloğlu and Boydak (2019) applied Periodic Acid Schiff (PAS) and (Gordon Sweeth) GS staining methods on partridge pecten oculi. They reported that PAS positive reaction was observed around blood vessels, capillaries and pigment cells in the PAS staining method. However, they reported that reticular fibers were not observed in the Gordon Sweet staining method (Kuloğlu and Boydak, 2019).

Optic Nerve: Nervus opticus (Cr2) is the second of 12 cranial nerves known as Nervi craniales (encephalici) and transmits visual information from the retina to the brain. Since it originates from embryonic retinal ganglion cells, which is a diverticulum located in the diencephalon, it cannot regenerate after being cut (Oğul, 1996; Anderson, 1969). Nervus opticus (Cr2) carries special somatic afferent nerve fibers related to the sense of sight. Afferent nerve fibers originate from multipolar ganglion cells in the retina. There are also a small amount of efferent fibers, but their origin is not clear. Cr2 contains an average of 1,200,000 fibers. Nervus opticus (Cr2), which is approximately 4 cm long, consists of four parts: pars intraocularis (1 mm), pars intraorbitalis (25-35 mm), pars intracanalicularis (7 mm) and pars intracranialis (10-15 mm) (Arıcı & Elhan, 1997; Williams *et al*., 1995; Snell, 2000; Radius, 1994). Nervus opticus is surrounded by the cerebral cortex. In other words, the "Dura mater", "Arachnoid" and "Piamater" layers that make up the cerebral cortex also surround the optic nerve. The retinal nerve fiber layer gradually becomes thinner and extends from the optic disc to the periphery of the retina. If nerve fibers forming the visual pathways in the optic nerve are damaged in any region for any reason such as tumor, cut, bleeding, the damaged area cannot transmit bio-electrical nerve impulses forward. As a result, since the brain cannot perceive the stimuli of the retina passing through that region, it cannot see a certain region of the visual field of the eye (Duus, 2001). Therefore, knowing the cellular organization of the optic nerve very well is very important in the precautions to be taken against optic nerve damage.

In general, a nerve fiber consists of axons surrounded by a special sheath derived from cells of ectodermal origin. Nerve fibers differ in their sheaths depending on whether they are located in the peripheral or central nervous system. All the axons of the peripheral nervous system are surrounded by squamous cells called Schwann cells lined up along the extension. Schwann cells form a multilayered membranous wrap around most axons. This wrapping is called myelin, and those wrapped around it are called myelinated fibers. There are no Schwann cells in the central nervous system. Here, glia cells (oligodendrocytes) form the myelin sheath (Soydan, 1992; Junqueira *et al*., 1998). The myelin sheaths of axons in Cr2 are not formed by Schwann cells as in other cranial nerves, but by oligodendrocytes as in the central nervous system (Taner, 2002; Burkitt *et al*., 1993; Leeson *et al*., 1985). An artery and a vein, which are the vessels of the retina, pass through the center of the nervus opticus (Cr2). The arteria centralis retinae, which progresses towards the bulbus oculi, is separated from the arteria opthalmica, and the vena centralis retinae pours into the arteria opthalmica (Krstic, 1991; Taner, 2002). Kuloğlu (2022), reported numerous vascularizations in the connective tissue located in the center of the optic nerve in the partridge nerve (Cr2) in their study.

Nervus opticus (Cr2) is known as a tract that lies between the ganglion cells in the retina and the diencephalon and actually belongs to the central nervous system. Since it develops from the diencephalon embryologically and is surrounded by meningeal structures throughout its course, it is considered as an extension of the central nervous system, not a peripheral nervous system (Gökmen, 2003; Arıncı, 1994). It is known that the nervus opticus (Cr2) has a cylindrical structure in intraorbital sections (Wagner *et al*., 1997; Arıncı & Elhan, 1993). In the study conducted on partridge (*Alectoris chukar*) optic nervus (Cr2), it was reported that the optic nervus has a cylindrical structure (Kuloğlu, 2022).

Harderian Gland: In the research conducted by Brownscheidle and Niewenhuis (1978) on albino rats and Watanabe (1980) on mice, two distinct epithelial structures, Type A and B, were identified in the Harderian gland. They noted that Type A cells are more abundant than Type B cells. While Type A cells contain large secretory granules with a lipid-like and filamentous substance, Type B cells generally possess smaller secretory granules. Both cell types feature short microvilli on their apical surfaces. These cells are also referred to as light and dark cells (Woodhouse and Rhodin 1963, Tsutsumi *et al*. 1966, Bucana and Nadakavukaren 1973). However, some researchers (Chemes *et al*. 1977, Sinowartz and Amselgrober 1986) suggested that the two cell types arise from errors during preparation, while others (Tsutsumi *et al*. 1966, Lopez *et al*. 1992) argued that they represent the same cell in different metabolic stages (Kuloğlu, 2022).

The Harderian gland in poultry can be categorized into three types according to their lobular structures and the epithelial cells lining the glandular corpus and ducts (Burns 1992). Type I Harderian gland, primarily found in domestic birds like chickens, is tubuloalveolar and comprises a single lobe made up of prismatic epithelial cells. Type II Harderian gland, commonly observed in ducks, features prismatic structures with dark cells and consists of single-lobed tubular formations. Type III Harderian gland exhibits both tubular and tubuloalveolar structures and is frequently found in crows (Burns 1992). In poultry, the ducts of the Harderian gland are categorized into primary, secondary, and central ducts. The secretions from the corpus glandulas located in the lobules are drained into the central ducts via the primary and secondary ducts. Both the primary and secondary ducts have two cell types: one type consists of cubic cells with microvilli on their apical surfaces, while the other type comprises polymorphic cells situated beneath and between these cubic cells. These polymorphic cells are referred to as dark cells due to the dense staining of their nuclei and cytoplasm (Olah *et al*. 1992). Additionally, plasma cells, plasmablasts, and lymphocyte infiltrations are present in these ducts (Burns and Maxwell 1979; Kuloğlu, 2022).

Many researchers (Shinoda 1958, Sakai 1981, Payne 1994, Willem *et al*. 2007) have noted that the Harderian gland typically has a single draining duct, whereas the lacrimal and nictitant glands possess multiple draining ducts (Sakai 1981). Loewenthal (1896) studied the Harderian and nictitant glands across various mammalian species (including cats, dogs, sheep, calves, horses, pigs, rabbits, hedgehogs, guinea pigs, and white mice) and proposed that the number of draining ducts could be a significant factor in their differentiation. In research on deer, Miessner (1900) observed that the single duct of the Harderian gland bifurcates and opens at two points on the bulbar surface of the palpebra tertia (PT). Additionally, Pütter (1903) stated that whales also have a considerable number of draining ducts in their Harderian glands. Sakai (1981) indicated that the ducts responsible for transporting secretions in the Harderian gland should not be considered, as their origins and numbers vary significantly across species. He argued that the Harderian gland functions as an independent structure separate from the palpebra tertia (PT) due to the differences in their openings into the PT. Plasma cells derived from the bursa of Fabricii have been identified in the Harderian gland (Wight *et al*. 1971, Burns 1975, Glick and Olah 1981, King and McLelland 1984).

These cells play a crucial role in protecting the eye from infections by producing antibodies in response to local antigenic stimulation (King and McLelland 1984). In domestic poultry, the Harderian gland is thought to serve as an alternative central lymphoid organ to the bursa of Fabricii (Glick and Olah 1981). Plasma cells in the poultry Harderian gland are found within the interlobular connective tissue. It has been noted that the B-lymphocytes generated here migrate to secondary lymphoid organs (Bang and Bang 1968, Aitken and Survashe 1977). Rothwell *et al*. (1972) found that the plasma cells in poultry exhibit ultrastructural similarities to mammalian plasma cells and share common histochemical characteristics. It has been noted that plasma cells in the Harderian gland are capable of synthesizing IgA (Mueller *et al*. 1971, Russel 1993, Russel and Koch 1993) and IgG (Russel 1993, Russel and Koch 1993), making the gland a crucial organ for producing lacrimal IgA against the Newcastle virus. One of the unique characteristics of the poultry Harderian gland is the aggregation of plasma cells within the connective tissue. The number of plasma cells is greater in Type I Harderian gland compared to Type II. An increase in plasma cell numbers with age is seen only in Type I Harderian glands (Wight *et al*. 1971). In Type III Harderian glands, plasma cells are found solely in the tubuloalveolar regions. It has been suggested that the development of Harderian glands is influenced more by the evolutionary progress of the species than by environmental conditions, with Type II Harderian glands appearing in more primitive poultry (ducks) and Type III in more advanced poultry (crows) (Burns 1975).

In a study examining various mammalian species (Aitken and Survashe 1977), plasma cells in the Harderian gland were found to be clustered in hamsters, gerbils, and pigs, but were present in very small quantities in rats and mice. Loewenthal (1892a) published the first article on the Harderian gland, detailing its histology in hedgehogs. In a subsequent study (Loewenthal 1892b), he provided significant information into the histology of the Harderian glands in various species, including white mice, pigs, rats, guinea pigs, calves, sheep, and horses. Both studies noted the presence of flattened, squamous nucleus between the connective tissue and the secretory epithelium, although they did not identify these as myoepithelial cells (Loewenthal 1892a; b). Over the next two decades, the histology and embryology of the Harderian gland were investigated by numerous researchers (Loewenthal 1896, 1900, Taddei 1900, Sundwall 1907, Loewenthal 1912, 1913a, 1913b, Mobilio 1913, Loewenthal 1916), but myoepithelial cells were not mentioned in their findings. It was Hauschild (1914) who first referred to these cells, albeit categorizing them as connective tissue cells. The first description of myoepithelial cells in the Harderian gland of rats was provided by Derrien and Turchini (1924).

Sakai (1981) noted that nerve endings are associated with the cells of the corpus glandula or myoepithelial cells in rabbits and hamsters. It was reported that myoepithelial cells are between the secretory epithelium and their basal lamina in camels (Fathel-Bab *et al*. 1991), turkeys (Maxwell *et al*. 1986), and domestic poultry (Rothwell *et al*. 1972). Möllendorf (1927) indicated that myoepithelial cells occupy a position similar to those in salivary, sweat, mammary, and lacrimal glands, specifically between the secretory epithelium and the basement membrane. Chiquoine (1958) described these cells as star- or spider-shaped, featuring a nucleus and numerous cytoplasmic extensions, and positioned between the secretory epithelial cells and the basement membrane. He also noted that the nuclei of myoepithelial cells are distinctly visible under phase-contrast microscopy. Kuloğlu (2016) stated that the Harderian gland of henna partridges is located at the medial angle of the eye within the bulbus oculi. She described the gland as light pink in color, with convex and concave surfaces that correspond to the shape of the bulbus oculi, having a smooth surface resembling a crescent moon, and noted that it is not associated with the cartilage palpebra tertia (CPT) (Kuloğlu, 2016; Kuloğlu and Boydak, 2024). Çalışlar (1984) observed that the Harderian gland in chickens was also not associated with the CPT, unlike in other domestic animals such as cattle and pigs. He found that it was much larger and more developed than the lacrimal gland, displaying pinkish, light brown, or reddish colours and an irregular rectangular shape that conforms to the bulbus oculi. Similar descriptions of the gland's structure were reported by Fourman and Ballatyn (1967) in geese, Brobby (1972) in domestic ducks, Altunay and Kozlu (2004) in ostriches, Boydak and Aydın (2009) in domestic geese, Mobini (2012) in domestic chickens, Önal and Çınar (2013) in henna partridges, Bejdic *et al*. (2014) in laying hens, and Kleckowska *et al*. (2015) in Bilgorajska geese.

Çalışlar (1984) noted that in chickens, the Harderian gland is encased in a weak connective tissue capsule and features a main duct running along its longitudinal length. In a study on domestic ducks, Brobby (1972) reported that the Harderian gland is surrounded by a connective tissue capsule containing smooth muscle cells, tight collagen fibers, nerve fibers and blood vessels. Similar findings were presented by Boydak and Aydın (2009) in domestic geese, Kozlu *et al*. (2010) in ostriches, and Mobini (2012) in domestic chickens, all stating that the Harderian gland is covered by a thin connective tissue capsule. Mobini (2012) also identified blood vessels, parasympathetic nerve fibers, as well as collagen, elastic, and reticular fibers within the Harderian gland of domestic chickens. Boydak and Aydın (2009) observed collagen and reticular fibers in the connective tissue capsule of the Harderian gland in domestic geese, while Kozlu *et al*. (2010) made similar findings in ostriches. Liman and Gülmez (1996) found in their study on French white geese that the volume and size of the organ increased by the 21st day of hatching, along with thickening of the connective tissue between the lobules and the capsule. Kuloğlu (2016) pointed out that henna partridge Harderian gland is encased in a thin connective tissue capsule with smooth muscle fibers, nerve fibers, tight collagen fibers, reticular fibers and blood vessels (Kuloğlu 2016; Kuloğlu and Boydak, 2024). Studies have reported that the capsule surrounding the Harderian gland divides the gland into lobes and lobules in various species, including mice (Watanabe 1980), rats (Djeridane 1994), French white geese (Liman and Gülmez 1996), desert lizards (Sabry and Al-Ghaith 2000), ostriches (Altunay and Kozlu 2004), mallard ducks (Dimitrov and Nikiforov 2005), armadillos (Marcos and Affanni 2005), piglets (Munkeby *et al*. 2006), broiler and domestic chickens (Khan *et al*. 2007), domestic geese (Boydak and Aydın 2009), ospreys (Kozlu *et al*. 2010), domestic chickens (Mobini 2012), and henna partridges (Önal and Çınar 2013). In her study on henna partridges, Kuloğlu (2016) observed that the connective tissue capsule surrounding the organ extends septa into the gland, dividing it into lobes. Thinner connective tissue septa, distinct from the interlobar septum, further subdivide the lobes into smaller lobules. She also noted the presence of medium-sized blood vessels and nerve fibers at the junctions where the lobes come into contact. Studies have indicated that the Harderian gland features a compound tubuloalveolar structure in various species, including mice (Watanabe 1980), rats (Djeridane 1994), French white geese (Liman and Gülmez 1996), desert lizards (Sabry and Al-Ghaith 2000), tree mice (Pradidarcheep *et al*. 2003), ostriches (Altunay and Kozlu 2004), ospreys (Kozlu *et al*. 2010), mallard ducks (Dimitrov and Nikiforov 2005), armadillos (Marcos and Affanni 2005), piglets (Munkeby *et al*. 2006), broiler and domestic chickens (Khan *et al*. 2007), dolphins (Ortiz *et al*. 2007), domestic geese (Boydak and Aydın 2009), domestic chickens (Mobini 2012), henna partridges (Önal and Çınar 2013), and henna partridges (Kuloğlu 2016; Kuloğlu and Boydak, 2024). Brooby (1972) observed that the corpus glandulae of the Harderian gland in domestic ducks are branched, allowing their secretions to flow into a central lumen. Boydak and Aydın (2009) noted that in domestic geese, the Harderian gland folds into the lumen of the corpus glandula. According to Sakai (1981), the Harderian gland comprises multiple lobes arranged around a central duct, with each lobe containing its own central lumen and corpus glandula, where the corpus glandulae are oriented radially towards the lumen. In her research on henna partridges, Kuloğlu (2016) found that the corpus glandulae of their Harderian gland are also branched, with epithelial cells draining their secretions into the central lumen. She indicated that the Harderian gland of the henna partridge consists of several lobes surrounding a primary draining duct, with each lobe having its own primary duct and the corpus glandulas positioned around this duct (Kuloğlu 2016; Kuloğlu and Boydak, 2024).

Studies have shown that the corpus glandulas of the Harderian glands are lined with high columnar epithelial cells, as reported by Maxwell *et al*. (1986) in turkeys, Liman and Gülmez (1996) in French white geese, Altunay and Kozlu (2004) in ostriches, Yaren (2008) in female pheasants, Boydak and Aydın (2009) in domestic geese, Kozlu *et al*. (2010) in ospreys, and Mobini (2012) in domestic chickens. Önal and Çınar (2013), Kuloğlu (2016), Kuloğlu and Boydak (2024) noted that the corpus glandulas in the Harderian gland of henna partridges are made up of either low or high prismatic epithelial cells. Fathel-Bab *et al*. (1991) found myoepithelial cells between the secretory epithelial cells and the basement membrane in camels. In their study on turkeys, Maxwell *et al*. (1986) noted that myoepithelial cells are located beneath the columnar secretory epithelium and are associated with the basement membrane. Similarly, Rothwell *et al*. (1972) observed that in domestic chickens, myoepithelial cells are localized between the secretory epithelium and the basal lamina. In contrast, Kuloğlu (2016) and Kuloğlu and Boydak (2024) found that myoepithelial cells were present on the basal surfaces of the epithelial cells lining the walls of the corpus glandula and draining ducts in the Harderian gland of henna partridges.

In studies conducted by Boydak and Aydın (2009) on domestic geese, Kozlu *et al*. (2010) on ospreys, and Mobini (2012) on domestic chickens, no goblet cells were identified among the epithelial cells of the corpus glandula. Kuloğlu (2016) and Kuloğlu and Boydak (2024) also noted the absence of goblet cells between the corpus glandula in the Harderian gland of henna partridges. However, goblet cells were observed among the epithelial cells of the main draining duct (Kuloğlu 2016; Kuloğlu and Boydak, 2024). Additionally, research by Yaren (2008) on female pheasants, Boydak and Aydın (2009) on domestic geese, Kozlu *et al*. (2010) on ospreys, Mobini (2012) on domestic chickens, Önal and Çınar (2013), Kuloğlu (2016) and Kuloğlu and Boydak (2024) on henna partridges, the presence of a single central duct with a large lumen in each lobe of the Harderian gland, alongside the primary draining duct was reported. Yaren (2008) found that the epithelial cells in the primary duct exhibit a single-layered columnar structure, whereas those in the main draining duct have a single-layer cuboidal epithelium. In contrast, Önal and Çınar (2013), Kuloğlu (2016), Kuloğlu and Boydak (2024) stated that the epithelial cells in both the main draining duct and primary draining duct of the henna partridge Harderian gland display characteristics of a single-layered cuboidal epithelium. Studies on turkeys and ducks (Maxwell and Burns 1979), chickens (Scott *et al*. 1993), broilers and domestic chickens (Khan *et al*. 2007), domestic geese (Boydak and Aydın 2009), ospreys (Kozlu *et al*. 2010), and henna partridges (Önal and Çınar 2013) reported a significant presence of plasma cells located just beneath the connective tissue capsule surrounding the gland, within the septa separating from the capsule, and around the corpus glandula and draining ducts. Kuloğlu (2016) and Kuloğlu and Boydak (2024) noted that plasma cells were found in the connective tissue septa situated just below the connective tissue capsule of the henna partridge Harderian gland and around the corpus glandula. They also observed a substantial number of plasma cells surrounding the gland's primary ducts and the main draining duct (Kuloğlu 2016; Kuloğlu and Boydak, 2024).

Tongue: The diversity of food sources has led to various adaptations in bird species living in different habitats (El-Bakary, 2011). Therefore, birds differ in the development of their beak, tongue and palate (King and McLelland, 1984; Dehkordi *et al*, 2010). As a reflection of different lifestyles, the tongue plays an important role in food intake and swallowing and shows significant morphological differences (Dehkordi *et al*, 2010; Parchami *et al*, 2010). Gardner (1926) classified poultry tongues into two groups based on their function and adaptations; Harrison (1964) into five groups based on their specialization for eating, tasting, touching, swallowing and collecting food; and King and Mclelland (1984) and O'Malley (2005) into three groups based according to the way they collect, process and swallow food. As a result, as in mammals, feeding habits vary greatly in the microscopic structure of the poultry tongue (Dehkordi *et al*, 2010; Parchami *et al*, 2010). Histological and histochemical characteristics of poultry tongue glands have been determined by studies on domestic poultry (Gargiulo *et al*, 1991; Taib and Jarrar, 1998; Arthitvong *et al*, 1999; Liman *et al*, 2001; Kum, 2002), game animals (Crole and Soley, 2010; Pasve *et al*, 2010; Santos *et al*, 2011) and some wild birds (Jackowiak and Godynicki, 2005; Al-Mansour and Jarrar, 2007; Dehkordi *et al*, 2010). Although the structure of the glands in the upper digestive tract of many bird species has been described, there is no consensus on the localization and nomenclature of the tongue glands (Crole and Soley, 2009, 2010). Liman *et al* (2001) named the tongue glands as preglottal and laryngeal glands in a study on quail tongue. In chicken (Hodges, 1974; Nickel *et al*, 1977) they classified the tongue glands as anterior and posterior. In this study, as in chicken (Hodges, 1974; Nickel *et al*, 1977) and quail (Capacchietti *et al*, 2009), the glands located in the body of the tongue were named as anterior tongue glands and the glands located in the root were named as posterior tongue glands.

Although the most common gland type in bird species is tubular, there are also simple branched tubuloalveolar, alveolar and compound alveolar gland structures (Crole and Soley, 2010). Kuloğlu (2016) reported that the tongue glands of the partridge (*Alectoris chukar*) have a simple branched tubular gland structure and that the anterior tongue glands are serous and seromucous, while the posterior tongue glands are mucous. In quail (Taib and Jarrar, 1998; Liman *et al*, 2001), rostral tongue glands gave a PAS-negative reaction while caudal tongue glands gave a PAS-positive reaction. In chickens, anterior and posterior tongue glands were reported to give a strong PAS-positive reaction (Gargiulo *et al*, 1991; Arthitvong *et al*, 1999; Kum, 2002). Kuloğlu (2016) reported that anterior tongue glands gave a stronger PAS-positive reaction than posterior tongue glands in the tongue glands of partridge in PAS staining method. WhileTaib and Jarrar (2001) reported that no reaction was observed in the anterior glands in the AB pH=2.5 staining method in adult quail (Coturnix coturnix) tongue glands, Kuloğlu (2016) reported that the anterior tongue glands gave a stronger AB-positive reaction than the posterior tongue glands in chukar partridge tongue using AB pH=2.5 staining method.

Liver: The liver is a multifaceted organ that processes nutrients absorbed from the digestive tract, storing them for use by other parts of the body or releasing them into the bloodstream. It serves as a crucial transition point between the digestive system and the circulatory system. Most substances absorbed from the small intestine reach the liver through the portal vein, while lipids are transported via the lymphatic vessels. Nutrient-rich blood from the digestive organs is carried to the liver sinusoids through the portal vein, where it then diffuses into neighboring hepatocytes. As the largest gland in the body, the liver plays a central role in maintaining energy supply. It functions as both an endocrine and exocrine gland, and is involved in the metabolism of proteins, fats, and carbohydrates, the synthesis and secretion of bile, and detoxification processes. In poultry, the liver is situated in the Cavum peritonei hepatis ventralis and is divided into two lobes: the larger right lobe (lobus hepatis dexter) and the smaller left lobe (lobus hepatis sinister). Generally, the liver tends to be larger in insectivorous and piscivorous species, while it is smaller in carnivorous and granivorous species.

The liver is covered by membranes known as the tunica serosa on the outside and the tunica fibrosa, which tightly encases the organ's parenchyma on the inside. The lobes' shapes vary among species: the left lobe is ellipsoid in chickens, bean-shaped in ducks, and wide yet shorter than the right lobe in geese. The right lobe, on the other hand, is heart-shaped in chickens and tongue-shaped in ducks, while in geese, it is wider and longer than the left lobe. In poultry, the two liver lobes are connected at the midline by a parenchymal bridge. In many species, such as pigeons and ostriches, the right lobe is typically larger than the left. However, in some species, the lobes may be equal in size, and the left lobe is further divided into ventral and dorsal sections in domestic chickens. While the liver parenchyma of poultry resembles that of mammals, there are notable histological differences between the two (Çıraklı and Kuloğlu, 2022). In the studies by Selman (2013) in Eurasian coots, Faraj and Al-Baurity (2016) in starlings, Karan *et al*. (2018) in Japanese quail, it was observed that the liver consists of two lobes and has a dark red-brown color and that the two lobes are joined by a parenchymal bridge in the midline.

Moslem (2015) reported that the liver of ostriches and poultry is dark red-brown in both species and that the liver of ostriches consists of four lobes, while chickens consists of two lobes. Çıraklı and Kuloğlu (2024), similar findings was observed that the liver of the Chinese goose (*Anser cygonides*) is dark red brown in color and consists of two lobes, lobus hepatis dexter and lobus hepatis sinister and these two lobes are joined by a parenchymal bridge in the middle of the liver. Bahadır *et al*. (1992) found that the liver is between the 2nd and 8th costa in domestic geese, between the 3rd and the last costa in domestic duck and starts from the 4th costa and exceeds the last costa in Pekin. Çıraklı and Kuloğlu (2024), it was determined that Chinese goose (*Anser cygnoides*) liver is between the 2nd and 8th costa as in domestic goose. Çıraklı and Kuloğlu (2024), it was determined that the right lobe is larger than the left lobe as reported by Nickel and Seiferle (1977) in domestic birds, Bahadır *et al*. (1992) in domestic ducks, domestic geese and pekin, Denbow (2015) in Turkeys, Taşçı *et al*. (2018) in hawks, Karan *et al*. (2018) in Japanese quail, Zaefarian *et al*. (2019) in domestic poultry. However, in the studies by Taşbaş (1978) in turkeys and Klasing (1999) in birds, it was reported that both lobes are of equal size.

Nickel and Seiferle (1977) found that the right lobe is longer than the left lobe in ducks and geese and Karan *et al*. (2018) found that both lobes are of equal length in Japanese quails. Çıraklı and Kuloğlu (2024), it was observed that the right lobe is longer than the left lobe. In the studies by Taşbaş (1978) in chickens, roosters and turkeys, Denbow (2015) in domestic birds and turkeys, Karan *et al*. (2018) in Japanese quails, Zaefarian *et al*. (2019) in domestic poultry and turkeys, it was reported that the right lobe of the liver is in one piece, while the left lobe is divided into two lobes, lateral and medial, with a notch. Similar findings were also found in the Çıraklı and Kuloğlu (2024) in Chinese goose (*Anser cygnoides*), the right lobe being one piece and the left lobe is divided into two lobes, lateral and medial, with a notch. Taşbaş (1978) reported that the gallbladder is spindleshaped in chickens, as reported by Karan *et al*. (2018) in Japanese quail. Nickel and Seiferle (1977) stated that the gallbladder is pear-shaped in domestic birds. Çıraklı and Kuloğlu (2024), it was observed that the gallbladder of the Chinese goose (*Anser cygnoides*) is in the form of an elongated tube. In the studies by Bahadır *et al*. (1992) in ducks and geese, Taşbaş (1978) in chickens and turkeys, it was reported that the gallbladder is located on the dorsal surface of the right lobe of the liver and does not pass through the caudal part. In their study in Japanese quail, Karan *et al*. (2018) reported that the gallbladder was on the dorsal surface of the right lobe of the liver and passed through the caudal part. Çıraklı and Kuloğlu (2024), it was observed that the gallbladder is on the dorsal surface of the right lobe of the liver and does not pass through the caudal part.

In the studies by Selman (2013) in Eurasian coot and Al-Abdulla (2014) in mallard ducks, it was reported that the liver consists of many lobules, which are separated by a thin connective tissue. Çıraklı and Kuloğlu (2024), it was observed that the Chinese goose (*Anser cygnoides*) liver consists of many lobules separated from each other by a thin connective tissue. Çıraklı and Kuloğlu (2024), it was observed that liver of Chinese goose (*Anser cygnoides*) does not have the typical lobule structure, as reported by Swatland (1994) in poultry. In the studies by Selman (2013) in Eurasian coots, Hamodi *et al*. (2013) in guinea fowl, lovebirds and gulls, Iqbal *et al*. (2014) in chickens, Al-A'Aaraji (2015) in male wild turkeys, Faraj and Al-Baurity (2016) in starlings, Karan *et al*. (2018) in Japanese quail, Zaefarian *et al*. (2019) in domestic poultry and turkeys, they observed oval and centrally located hepatocytes, remark cords consisting of radially arranged hepatocytes, sinusoids separating remark cords, phagocytically active Kupffer cells, bile ducts consisting of single-layer prismatic cells involved in secretion production and hepatic artery portal vein and central vein involved in circulation. Çıraklı and Kuloğlu (2024), hepatocytes, remark cords, sinusoids, hepatic artery forming the Kiernan's space, portal vein and bile duct, kupffer cells and central vein were observed in the liver of Chinese goose (*Anser cygnoides*).In their study in poultry, Zaefarian *et al*. (2019) found that hepatocytes in the liver have a complex cell structure with large nuclei and abundant mitochondria. Similarly, Çıraklı and Kuloğlu (2024), hepatocytes were determined to have a complex cell structure with large nuclei and abundant mitochondria.

Bursa Fabricii: The Bursa Fabricii is a spherical organ encased in connective tissue known as the "capsule" (Lupetti *et al*. 1990). This capsule features connective tissue trabeculae that divide the lymph follicles within the organ (Criaco *et al*. 2003). Structurally, the wall of the Bursa Fabricii comprises three layers: tunica mucosa, tunica muscularis, and tunica serosa, arranged from the innermost to the outermost layer. The mucosa is the thickest layer, characterized by folds (plicae) that extend into the organ's lumen (Tanyolaç 1999). Lymph follicles unique to the Bursa Fabricii are located within these mucosal folds. The epithelium of the tunica mucosa consists of two types: pseudostratified columnar epithelium in the interfollicular region (IFE) and a specialized epithelium (FAE) rich in lymphocytes that lacks a basement membrane over the follicles (Lupetti *et al*. 1990; Olah *et al*. Glick 1992; Kuloğlu, 2022). Aside from the interfollicular epithelium (IFE) that lines the inner surfaces of the plicae facing the lumen, each lymph follicle is covered by specialized epithelium known as follicle-associated epithelium (FAE) (Glick and Olah 1993). Scanning electron microscopy (SEM) reveals FAE cells appearing as circular spots interspersed among IFE cells (Davenport and Allen 1995). Notably, these FAE cells lack a basal lamina and are characterized by their prismatic shape. They are described as being more loosely attached to the underlying connective tissue compared to the pseudostratified columnar epithelial cells covering the plicae surfaces (Saifuddin *et al*. 1988).

FAE is supported by 2-5 layers of epithelial cells that stack on top of one another, which are extensions of corticomedullary

border cells (CMBC). Desmosomes connect the FAE to the supporting cells beneath it (Olah and Glick 1992; Kuloğlu 2022). Each plica contains numerous polyhedral follicles, with small amounts of connective tissue separating them. The tops of these follicles are supported by a network of reticular fibers and reticular cells (Hodges 1974). Each follicle consists of two functionally distinct regions: the cortex and the medulla. The medulla houses various cell types, including secretory cells, predominantly B lymphocytes, dendritic reticulum cells, macrophages, and T lymphocytes (Hodges 1974, Ratcliffe 1985). The cortex appears darker due to its high density of tightly packed small lymphocytes (Hodges 1974). Corticomedullary border cells (CMBCs) create a separation between the cortex and medulla, with a network of capillaries located just beneath the basement membrane (Hodges 1974, Tizard 1983, Bacha 1990). The pseudostratified columnar epithelial cells of the IFE that line the inner surfaces of the plicae extend into the follicles, merging with the lymphatic follicles. These follicles are flattened and positioned between the cortex and medulla, with their basement membranes interspersed (Maxwell 1985). Histologically, the absence of capillaries in the medulla of the follicles, combined with the presence of corticomedullary border cells (CMBC) resting on a prominent basement membrane at the cortex-medulla boundary, suggests the existence of a blood-bursa barrier between the blood supply and the medulla of the lymphatic follicles in the Bursa Fabricii during the period before involution (Hodges 1974, Kocaöz *et al*. 1997; Kuloğlu 2022).
The tunica muscularis comprises two layers of smooth muscle cells: an outer longitudinal layer and an inner circular layer. Major branches of blood vessels are found between these muscle layers at the base of each plica, providing nourishment to the organ and extending along the plicae. These blood vessels reach the innermost layer of muscle (Hodges 1974). Externally, the tunica muscularis is covered by a thin layer of tunica serosa, with loose connective tissue (subserosa) situated between the tunica serosa and tunica muscularis (Tanyolaç 1999).

The histological development of the Bursa Fabricii is nearly complete prior to hatching (Lupetti *et al*. 1990; Shiojiri and Takahishi 1991). Following hatching, the lymph follicles within the organ, which have reached their developmental maturity, enlarge during the initial weeks. However, no new lymphatic follicles are formed during this time. It has been estimated that upon completion of its development, the organ contains approximately ten thousand lymph follicles within its lamina propria (Ratcliffe 1985; Kuloğlu 2022). The wall structure of the Bursa Fabricii comprises three layers: tunica mucosa, tunica muscularis, and tunica serosa. This has been documented in various studies, including those by Ciriaco *et al*. (1985) on pigeons, Kocaöz (1993) on chickens, Onyeanusi *et al*. (1993) on guinea fowl, Gülmez and Aslan (1999) on domestic geese, Sarı and Kurtdede (2007) on turkeys, and Dirik (2011) on rock partridges, as well as in recent studies by Kuloğlu (2016) and Kuloğlu and Boydak (2024) on henna partridges. Research has shown that the tunica mucosa of the Bursa Fabricii features folds extending into the lumen, as reported in studies by Ciriaco *et al*. (1985) on pigeons, Kocaöz (1993) on chickens, Onyeanusi *et al*. (1993) on guinea fowls, Gülmez and Aslan (1999) on domestic geese, Sarı and Kurtdede (2007) on turkeys, Dirik (2011) on rock partridges, Khenenou *et al*. (2012) on broilers, Kuloğlu (2016) and Kuloğlu and Boydak (2024) on henna partridges.

Additionally, the lamina epithelium of the Bursa Fabricii is composed of two distinct types of epithelium: interfollicular epithelium (IFE) and follicle-associated epithelium (FAE), which was noted in the studies of Ciriaco *et al*. (1985) on pigeons, Kocaöz (1993) on chickens, Onyeanusi *et al*. (1993) on guinea fowls, Hupaya (1995) on broilers, Gülmez and Aslan (1999) on domestic geese, Sarı and Kurtdede (2007) on turkeys, Dirik (2011) on rock partridges, Khenenou *et al*. (2012) on broilers, Kuloğlu (2016) and Kuloğlu and Boydak (2024) on henna partridges. Research has confirmed the presence of lymph follicles containing cortex and medulla regions within the plicae of Bursa Fabricii. This has been documented in studies by Hashimoto and Sugimura (1976) on Peking ducks, Ciriaco *et al*. (1985) on pigeons, Onyeanusi *et al*. (1993) on guinea fowls, Kocaöz (1993) on chickens, Hupaya (1995) on broilers, Gülmez and Aslan (1999) on domestic geese, Sarı and Kurtdede (2007) on turkeys, Dirik (2011) on rock partridges, Khenenou *et al*. (2012) on broilers, Kuloğlu (2016) and Kuloğlu and Boydak (2024) in henna partridges. Sarı and Kurtdede (2007) reported the presence of lymphocytes, lymphoblasts, reticular epithelial cells (RECs), and macrophages in both the medulla and cortex of the Bursa Fabricii in turkeys. Similarly, Kuloğlu (2016) and Kuloğlu and Boydak (2024) observed lymphocytes, lymphoblasts, and macrophages within the cortex and medulla of the henna partridge Bursa Fabricii.

Tymus: The thymus gland is situated beneath the thyroid gland, in front of the thoracic cavity, and is encased by a thin connective tissue capsule (Şenol, Yeşil, 2022). Within the thymus lobes, reticular cells and lymphocytes are present, with variations in the number of lobes between the right and left sides, as well as among different poultry species (Sarıca, Karataş, and Gözalan, 2009). This gland plays a crucial role in activating lymphocytes shortly before and after birth, helping to protect the body from infections (Sarıca, Karataş, and Gözalan, 2009). Specifically in poultry, the thymus is responsible for the maturation of T lymphocytes, the elimination of autoreactive T cells, and the synthesis of thymic hormones (Sarıca, Karataş, and Gözalan, 2009). In poultry, the thymus is located on either side of the neck and consists of several lobes that are spaced along the sulcus jugularis. These lobes, which are flat-oval in shape, are embedded in subcutaneous connective tissue and typically number around seven on each side of the neck. The thymus begins at the level of the third cervical vertebra and extends down to the thyroid gland in the thoracic cavity. The lobes on the right side form the right half of the organ, while those on the left comprise the left half. The arrangement of the lobes on both sides aligns with the pathways of the N. vagus and V. jugularis in the neck region (Berktay, 2014).

Each lobe of the gland is encased in a connective tissue capsule, which consists of loose connective tissue and adipose tissue on the outside. The inner part of the capsule contains connective tissue threads and elastic fibers. Fine connective tissue separates the lobes into smaller lobules, and blood vessels that supply these lobules primarily run where the connective tissue compartments meet the capsule. Thin branches from these vessels extend into the connective tissue compartments, reaching the lobules (Berktay, 2014; Çinar *et al*. 2022). While the cortex and medulla can be distinguished within the lobules, the border between them is not sharply defined. Both the cortex and medulla form a porous structure made up of a network of reticulum cells supported by reticular fibers. Reticulum cells feature round, oval, or elongated oval nuclei with one or two nucleoli and finely dispersed heterochromatin. The pores in this network are filled with a mass of lymphocytes, predominantly small lymphocytes, especially in the cortex. The high density of lymphocytes in the cortex gives it a dark basophilic appearance in histological preparations (Berktay, 2014). The medulla contains fewer lymphocytes, resulting in a paler staining. The low density of lymphocytes allows for clearer visibility of the nuclei of the reticulum cells. Similar to mammals, round-shaped Hassall bodies are rarely found in the medulla of thymus lobules in poultry (Berktay, 2014; Çinar *et al.* 2022). Cystic structures, often referred to as diffuse Hassall bodies, arise from changes in reticulum cells within the thymus. Their formation begins with the development of small vesicles in the cytoplasm of certain reticulum cells in the medulla. As these vesicles fuse, they create large, round vacuoles which can completely fill the cell cytoplasm. The merging of multiple vacuoles leads to the formation of very large vacuoles and cystic structures. Typically, the lumens of these structures are filled with an eosinophilic substance, and their walls consist of reticulum cells. In addition to non-degenerated lymphocytes, the cyst content may also include cellular debris, such as dark basophilic granules derived from degenerated lymphocyte nuclei. These cystic structures, predominantly found in the medulla of the poultry thymus and identified as diffuse Hassall bodies, are considered to form during the destruction of lymphocytes rather than from degenerating reticulum cells (Berktay, 2014). The majority of epithelial-derived reticulum cells in the medulla are associated with these medullary cysts. Some cyst lumens contain PAS-positive material, while others may be empty. These large cysts can vary significantly in shape, and their lumens are often surrounded by numerous epithelial reticulum cells. Most cyst lumens are filled with a colloidal or granular substance, which includes remnants from cell destruction (Berktay, 2014; Çinar *et al.* 2022).

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