

## The Avian Lymphatic System

G.M. Cross  
Department of Animal Health  
University of Sydney  
Camden NSW 2570

The lymphatic system of the domestic fowl has been described in detail by Firth (1977), Rose (1981) and Payne and Powell (1984). Lymphatic tissue in general consists of reticulin fibres and fixed cells (macrophages and reticulin cells), as well as free cells (lymphocytes, plasma cells and granulocytes). In loose lymphatic tissue, fixed cells predominate, whereas in dense lymphatic tissue, free cells predominate. The avian lymphatic system may be divided into:

- a) primary lymphatic tissue (central), which consists of the thymus and cloacal bursa. This is antigen dependant, and in it incoming stem cells differentiate into immunologically competent B and T cells, which then migrate to the secondary lymphatic tissue; and
- b) secondary lymphatic tissue (peripheral), which consists of the spleen, bone marrow, mural lymphoid nodules and variable aggregations of lymphocytes throughout the body. Secondary lymphatic tissue is antigen dependent "effector" tissue, in which B and T cells mature into respective effector cells.

The stem cells which colonise the embryonic thymus and bursa originate in the area pellucida or embryo proper in birds. Late in embryonic development, stem cells may be found in the liver and spleen. In adult life they exist primarily in the bone marrow.

Lymphatic vessels are closely associated by connective tissue to the arteries in the trunk, and to the veins outside the trunk. These drain into the jugular and subclavian veins, the cranial vena cava, and the thoracoabdominal trunks (thoracic ducts). In the domestic fowl, the latter extend on either side of the aorta and drain into the cranial vena cava. The wall of lymphatic capillaries consists of a layer of flat endothelial cells. As the vessels increase in size they develop a layer of collagen and elastic fibres and a few smooth muscle cells. Along the course of these vessels may be found lymphatic plexuses. Valves are occasionally found in the larger lymphatic vessels.

"Lymphatic hearts" are muscular dilatations of the lymphatic vessels and occur in the embryonic stages of all species but persist into adult life only in ratites. They lie at the level of the second coccygeal vertebra between the origins of the m. flexor cruris medialis and the dorsal coccygeal muscles. They have three layers: an endothelial layer, a middle muscular layer and an outer fibrous layer.

## **Primary Lymphoid Tissue**

### **1. Thymus**

The epithelial portion of the thymus is derived from the 3rd and 4th branchial pouches and in the domestic fowl consists of 4-7 lobes extending from the 3rd cervical vertebra to the thyroid gland within the thoracic cavity. In some instances the thyroid gland may contain thymic tissue.

The thymus is a primary lymphoid organ and contains T cells which are derived from embryonic stem cells which colonise the embryonic thymus. The thymus increases in size to 17 weeks and then slowly regresses.

Each lobe is enclosed by a connective tissue capsule of collagen and elastic fibres. True septae pass inward from the capsule and divide the lobe into lobules, which may be further subdivided by septules into segments. Each lobule is indistinctly divided into cortex and medulla.

The cortex consists of densely packed small lymphocytes and a few medium-sized lymphocytes. Since the lymphocytes in the medulla are much larger and fewer, the medulla stains more lightly than the cortex. Reticular cells in the medulla form small, rounded islands called thymic corpuscles (Hassal's corpuscles). Also within the medulla are myoid cells. These contain myofibrils and are commonly found in the thymus of birds and reptiles, although their function is not known.

Thymic lymphocytes are derived from stem cells from the circulation. The main function of the thymus is as a maturation site in which stem cells differentiate into T lymphocytes which then populate the secondary lymphoid tissues. Endocrine-like cells at the cortico-medullary junction have been described. The thymus also contains B-lymphocytes, and in older birds contains germinal centres. The thymus thus also acts as a peripheral lymphoid organ, and in times of stress may become erythropoietic.

### **2. Cloacal Bursa**

The cloacal bursa (bursa of Fabricius) is a blind, dorsal diverticulum of the cloacal proctodeum. In the domestic fowl it is largely spherical, and its inner surface is thrown into a number of folds (plicae) which can partly obscure the lumen. It reaches maximum size in the domestic fowl (relative to body weight) at 3-6 weeks of age, and begins to regress at 8-12 weeks of age. It is completely regressed at sexual maturity (18-22 weeks of age), and disappears at 6 months to one year.

The wall of the bursa consists of three layers: a thin serosa, a muscularis and the mucosa. The mucosa is thrown into 10-15 folds, each of which contains numerous polyhedral lymphatic follicles (8-12,000 in the domestic fowl). Follicles are separated by a fine interfollicular septum consisting mainly of fibrous tissue. Each follicle consists of a central medulla enclosed by a cortex. In some ratites, cuckoos, and nocturnal raptors, however, the medulla is not enclosed by a cortex but lies between the cortex and the mucosal epithelium.

As in the thymus, the cortex stains more deeply because of its higher concentration of small lymphocytes. However, unlike in the thymus, the cortex and medulla of the follicles of the cloacal bursa are separated by a distinct basement membrane, capillaries and a thin layer of stellate reticular epithelial cells. Reticular epithelial cells form a supporting network for lymphocytes in the follicle. During regression, lymphocytes are lost from the cortex and medulla and the framework of reticular epithelial cells becomes more apparent.

The surface epithelium lining the inner surfaces of the plicae is a tall, columnar, pseudostratified epithelium.

The function of the bursa complements that of the thymus. It is primary lymphoid tissue which oversees the differentiation of B-lymphocytes from stem cells to fully mature plasma cells. The bursa also contains a small number of T cells. The bursa can also be involved in a local immunological response mainly via "cloacal drinking". It has been postulated that the fowl gains part of its immunity to environmental antigens in this way.

### **Secondary Lymphoid Tissue**

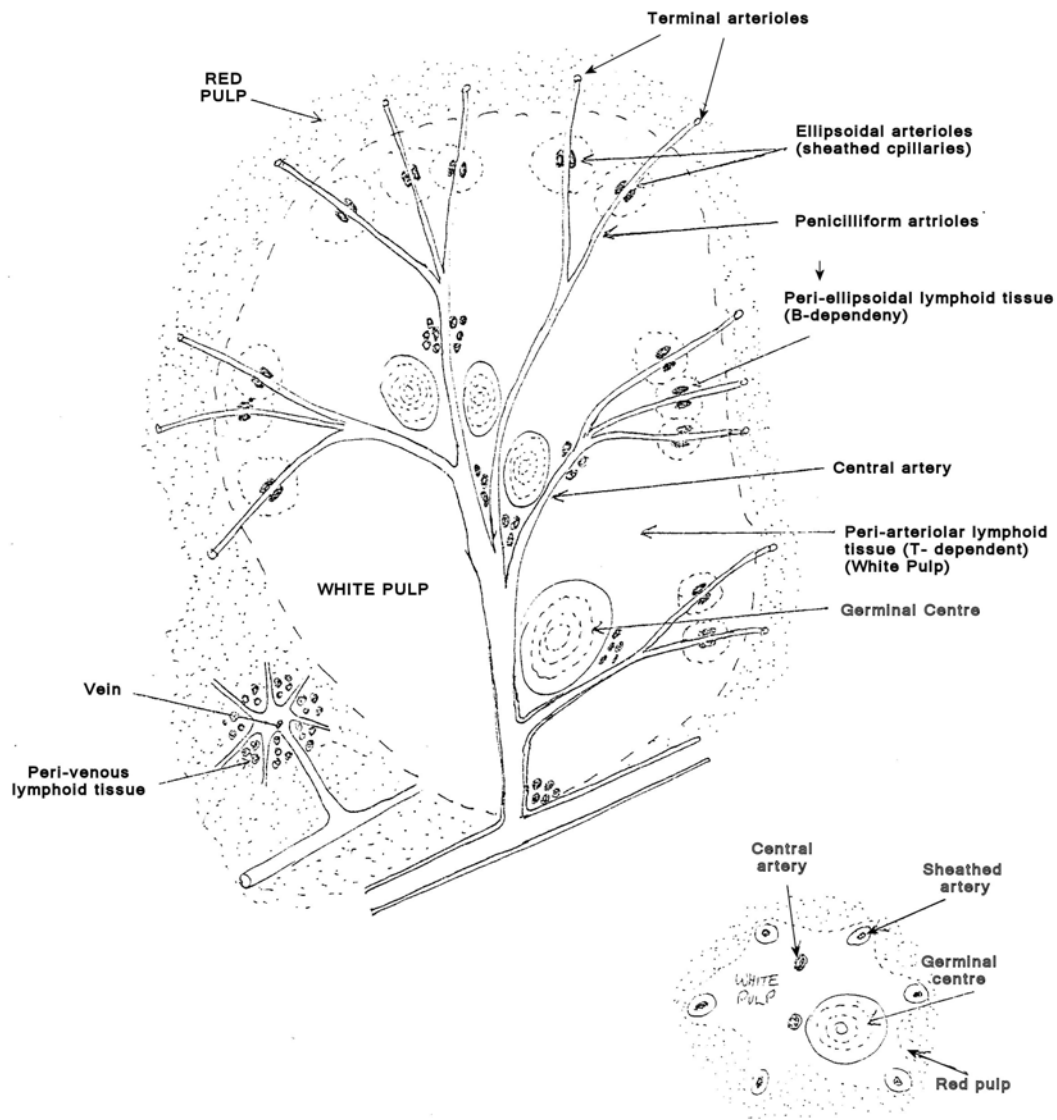
In avians, the secondary (peripheral) lymphoid tissue consists of the spleen, bone marrow, mural lymphoid nodules, lymphoid tissue in the digestive tract and oculonasal region, and the aggregated lymphoid nodules scattered throughout the body.

#### **1. Spleen**

The spleen in the domestic fowl and turkey is round to egg-shaped, while in aquatic birds it is triangular with a flat dorsal and convex ventral surface. It lies against the dorsal surface of the right lobe of the liver between the proventriculus and gizzard. The spleen functions as a peripheral lymphoid organ and also disposes of effete erythrocytes.

The connective tissue capsule of the spleen contains almost no smooth muscle and is covered by peritoneum. However, unlike the mammalian spleen, the avian spleen is not clearly subdivided by trabeculae arising from the capsule. Some workers claim that trabeculae do not exist in the spleen. The normal spleen is almost equally divided into red pulp (RP) and white pulp (WP). The WP is enclosed by RP and consists of islands of lymphocytes surrounding central arteries.

Radiating from these central arteries are the penicillar (penicilliform) arterioles, which, at the periphery of the WP, give rise to six to eight ellipsoidal arterioles (sheathed capillaries), small straight vessels with a cuboidal endothelium. These ellipsoidal arterioles are enclosed by reticular cells, forming the ellipsoid. In longitudinal section, ellipsoidal arterioles may be recognised by their parallel rows of endothelial nuclei. Blood from these vessels flows via "terminal arterioles" and empties directly into erythrocyte-filled spaces between the reticular cells of the RP. Blood from these spaces is collected by small veins arranged in a star-like manner (see Figure 1).



**Figure 1: Structure of Avian Spleen**

Varying amounts of lymphoid tissue surround the arteries and veins of the spleen. The ellipsoids are on the edge of the WP and lymphocytes surrounding them form the peri-ellipsoidal cuffs (B-lymphocytes). Lymphocytes surrounding arterioles form the peri-arteriolar sheaths and are T-lymphocytes. The latter make up the major part of the WP. The germinal centres (lymphoid follicles) of the WP, and the lymphocytes which surround them, are B-dependent. B-lymphocytes and antigen-bearing dendritic cells migrate from the peri-ellipsoidal cuff along the penicillary arterioles to their point of origin from the central artery, where they form germinal centres. Germinal centres are thus always associated with a central artery and are bordered by collagenous lamellae and crescentic sinuses which are connected with the venous system. Large follicles contain a corona of dark cells surrounding a light centre. Numerous mitoses may be present in germinal centres

## 2. **Bone Marrow**

The bone marrow functions as secondary lymphoid tissue - a source of B and T lymphocytes. It contains diffuse lymphoid tissue with germinal centres.

## 3. **Mural Lymphoid Nodules**

These are aggregations of lymphoid tissue associated with lymphatic vessels. They are very numerous and occur in all birds. They are usually confined to one side of a vessel and may protrude into the lumen. These nodules vary from diffuse aggregations of small lymphocytes up to organised tissue containing a number of germinal centres.

## 4. **Lymph Nodes**

In birds, lymph nodes apparently exist only in certain aquatic birds (ducks and swans). They may be found on the dorsal surface of the jugular vein in the angle formed by the jugular and vertebral veins (cervicothoracic nodes), and on each side of the lumbar aorta (lumbar nodes). The former occur as elongated structures surrounding the end-point of the cervical lymphatic duct.

The centre of the node consists of a sinus which is, in effect, an intranodal lymphatic vessel. This central sinus is surrounded by a zone of dense lymphoid tissue consisting of small lymphocytes. Outside this is a peripheral zone of loose lymphoid tissue containing small and medium lymphocytes. The central sinus opens directly into the peripheral zone, where filtration takes place.

## 5. **Lymphoid Tissue of the Digestive Tract**

- i) **Oral cavity and pharynx.** Lymphoid tissue is abundant in the oral cavity, particularly around the choanae and the openings of the auditory tubes.
- ii) **Small intestine.** Aggregations of lymphoid tissue occur regularly throughout the small intestine, and are analogous to the Peyer's patches (PP) of mammals. PP can be distinguished from the rest of the intestine by their thickened villi and large subepithelial accumulations of lymphoid cells.

The epithelium of normal intestinal villi and crypts consists of tall columnar cells of three types: chief or main cells; goblet cells; and enterochromaffin cells, whereas PP are separated from the intestinal lumen by a flattened epithelium which has a marked absence of goblet cells. PP epithelial cells stain positively for acid phosphatase (AP) whereas the columnar cells of normal epithelium do not. AP has been postulated as a chemotactic agent attracting lymphocytes to specific areas of lymphoid organs. Discontinuities in the epithelium over PP allow lymphocytes and plasma cells to be extruded into the intestinal lumen. The presence of AP in the PP epithelium might act as a mediator in this extension.

Beneath the epithelium the PP consist of dense aggregations of lymphoid cells, either as germinal centres or as diffuse lymphoid tissue. Germinal centres are surrounded by several layers of reticular cells separating them from the diffuse lymphoid tissue.

In Anas there are four regularly spaced, macroscopically visible, annular bands of lymphoid tissue in the proximal and distal parts of the jejunum and ileum. The bands are about 1 cm wide. The distal jejunal and proximal ileal rings are well defined, whereas the proximal jejunal and distal ileal rings are not. In Anser there are seven such rings.

- iii) **Caeca.** Large aggregations of lymphoid tissue, the "caecal tonsils", occur near the junction of each caecum with the rectum. They may be seen macroscopically as dilatations and thickenings of the necks of the caecae. Small lymphocytes predominate and germinal centres are common. Macrophages, plasma cells, mast cells and reticular cells are also present.

The lymphoid tissue of the digestive tract consists of both B and T cells. The B cells are concerned mainly with the production of IgA.

## 6. Oculonasal Lymphoid Tissue

The amount of lymphoid tissue in the oculonasal region varies between species. It is relatively large in galliformes but small in aquatic birds and passerines. This lymphoid tissue is found in the gland of the nictitating membrane (Harderian gland) and its draining duct, the lacrimal (lachrymal) gland and its duct, and the nasal (salt) gland and its duct.

All these glands have a compound tubuloacinar structure and produce a merocrine secretion. The secretions of the Harderian and lacrimal glands clean and moisten the cornea. In the interstitium of the Harderian gland are accumulations of plasma cells, which secrete antibodies into the exocrine secretion to confer local immunity in the eye and upper respiratory tract. The lacrimal gland is less well developed than the Harderian gland, the reverse of the situation in mammals. The lacrimal gland and its duct contain foci of small lymphocytes and germinal centres, and a few plasma cells. If the Harderian gland is removed, the number of plasma cells in the lacrimal gland increases as a compensatory mechanism. In the domestic fowl the nasal gland and its duct contain sub-epithelial plasma cells. The Harderian gland is necessary for protection against challenge by infectious bronchitis (IB) virus in chicks vaccinated against IB virus by this route.

## 7. Aggregations of Lymphoid Tissue in other Organs

The secondary lymphoid tissue which occurs in the alimentary canal and oculonasal region has been described. In addition, variable amounts of lymphoid tissue may be found in parenchymatous organs, the gall bladder, pancreas, lungs, endocrine glands, gonads, skin and peripheral nerves. Some authors refer to these areas of lymphoid tissue as "ectopic lymphoid areas". It is considered that they function as the equivalent of mammalian lymph nodes. They consist mainly of small lymphocytes with or without germinal centres.

### References

Firth, G.A. (1977). The normal lymphatic system of the domestic fowl. Vet.Bull. 47: 167-179.

Payne, L.N. and Powell, P.C. (1984). The Lymphoid System, in Physiology and Biochemistry of the Domestic Fowl, Academic Press, pp. 278-321.

Rose, M.E. (1981). Lymphatic Systems, in Form and Function in Birds, Vol. 2, Academic Press, pp. 341-384.