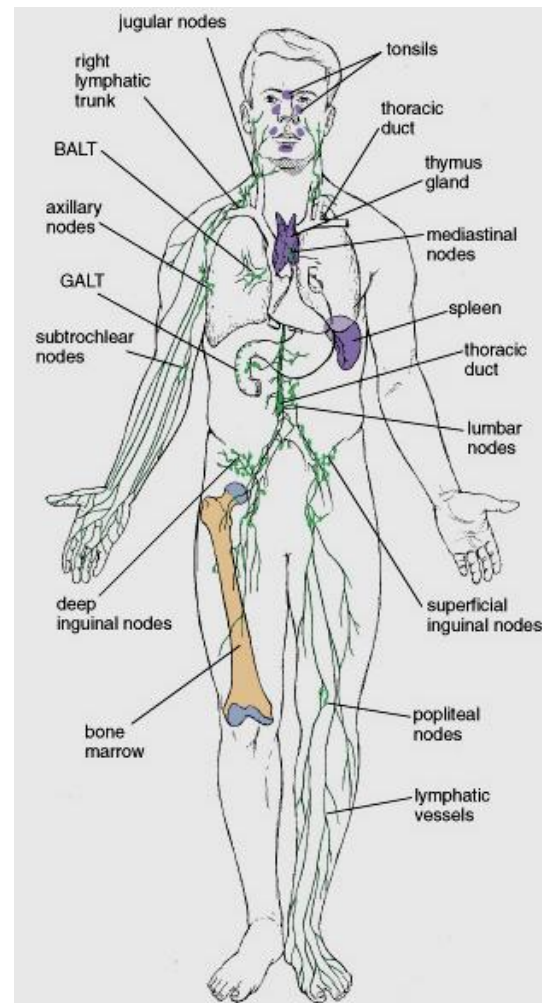


Lymphatic System

- The lymphatic system is vital to the defense mechanism against infectious agents.
- The cells which deal with these agents arose, developed, matured, and/or stored in lymphatic tissues.
- The lymphatic vessels and lymphoid organs are closely associated with the cardiovascular system.
- Lymph itself is a clear and slightly yellowish fluid derived from blood, and contains white blood cells (mainly lymphocytes).
- Lymph starts as blood fluid that passes through the tissue spaces and drained back by thin veinlike lymphatic vessels, and then re-enter the venous circulation.
- There are lymphoid cells in most tissues of the body arranged either loosely as aggregations, formed into encapsulated structures such as lymph nodes, or freely mobile as individual cells.



Types of lymphoid tissues:

1- The lymphoid tissue is divided into primary or secondary:

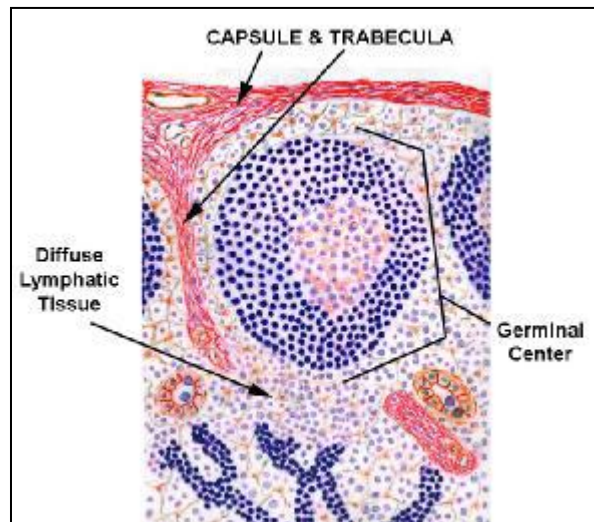
- **Primary lymphoid tissues** are the tissues in which lymphocytes are generated and differentiate into mature lymphocytes: such as bone marrow for B cells, and the bone marrow and the thymus for T cells.
- **Secondary lymphoid tissues** are the tissues in which immune responses are initiated, and the **lymphatic vessels** that connect them to the tissues and the bloodstream and thus to sites of infection; i.e. secondary lymphoid tissue brings antigen together with lymphocytes

2- The lymphoid tissue can be divided into diffuse or nodular:

- **Diffuse lymphatic tissue** consists of unorganized aggregation of lymphocytes. These can be found wherever localized conditions have attracted lymphocytes in large numbers, and vary greatly in size. Such aggregations are usually transient features.

- **Localized or Nodular lymphatic tissue** is always found surrounded by diffuse tissue and it is much more organized. The typical example of nodular lymphatic tissue is the germinal center, a highly ordered collection of B-lymphocytes found in some lymphatic organs. Not all lymphatic organs will contain germinal centers. Germinal centers never occur outside of those lymphatic system organs that can provide an appropriate environment for them.

Diagrammatic illustration of both diffuse and nodular lymphatic structures



The association of nodular/diffuse, germinal center/unorganized tissue can be found in lymph nodes, spleen, thymus gland, tonsils, appendix, and Peyer's patches of the ileum.

Lymph nodes

The lymph node is the most organized of the lymphatic organs and are found along larger lymphatic vessels. They are bean shaped, with a depression on one side (hilum). Blood vessels enter and leave the lymph node at the hilum, whereas lymphatic vessels enter at the periphery, and exit at the hilum. The lymph nodes act as "filters" for lymph as it passes through. Lymph is pushed through from the periphery of the node to its center, and then continues on its way back to join the venous circulation.

Structure of lymph nodes: lymph nodes are formed of stroma and parenchyma

- Lymph nodes have a discrete **CT stroma** in the form of capsule which sends **trabeculae** deep into the volume of the organ. The capsule acts as an overall envelope for the node, and is composed of dense irregular collagen with a few elastic fibers. Between the trabeculae, there is a network of reticular fibers and reticular cells that

form the framework of the lymph node. The meshes of this network are filled with lymphocytes, plasma cells and macrophages.

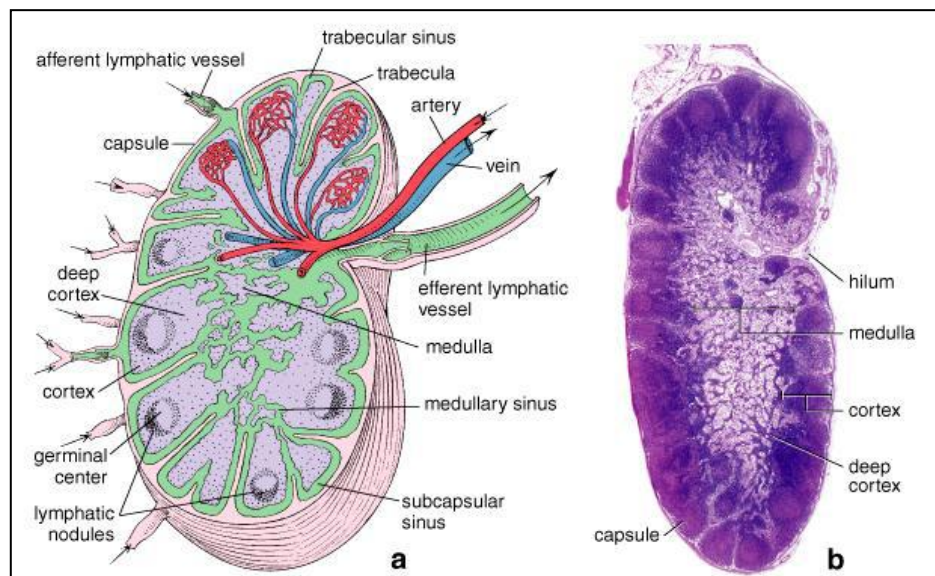
- **Lymph sinuses** are lymph spaces found in the cortex and medulla and are divided into subcapsular, cortical, and medullary lymph sinuses.
- **Parenchyma** of lymph nodes are formed of cortex and medulla
- **Cortex:** The cortex is further divided into outer cortex and deep or medullary cortex.

- o **The outer cortex is formed of**

- **Primary lymphoid nodules** which contain B-lymphocytes
- **Secondary lymphoid nodules** which contain germinal center.
- **Internodal lymphoid tissue** formed of diffuse lymphoid tissue.

- o **The inner or deep cortex** which is formed of diffuse lymphoid tissue that extend toward the medulla to join medullary cords. The inner cortex is the site of T-lymphocytes and is called thymus dependent zone.

- **Medulla:** is formed of aggregation of lymphoid tissues that branch and anastomose to form medullary cords. These cords contain small lymphocytes, plasma cells, and macrophages.



Structure of lymph node showing the cortex and medulla, as well as afferent and efferent lymphatic and blood vessels.

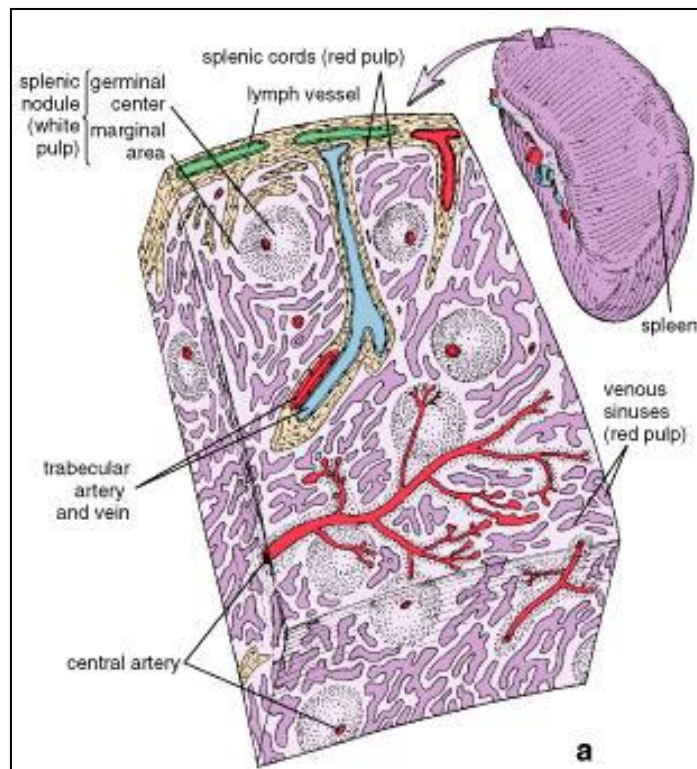
- **Function of lymph nodes:**

- Filtration of lymph
- Lymph nodes are the sites of antigen recognition.

Spleen

The spleen is a complex organ found in the abdominal cavity, carrying out filtration of particles and aged red cells from the blood, and responding to the presence of antigens. The spleen is really part of the circulatory system, but it is always described with the lymphatic organs because of the very large population of lymphocytes found in it. The spleen is a flaccid bag that serves as a storage site for blood.

Structure of spleen showing the capsule, trabeculae, red and white pulps



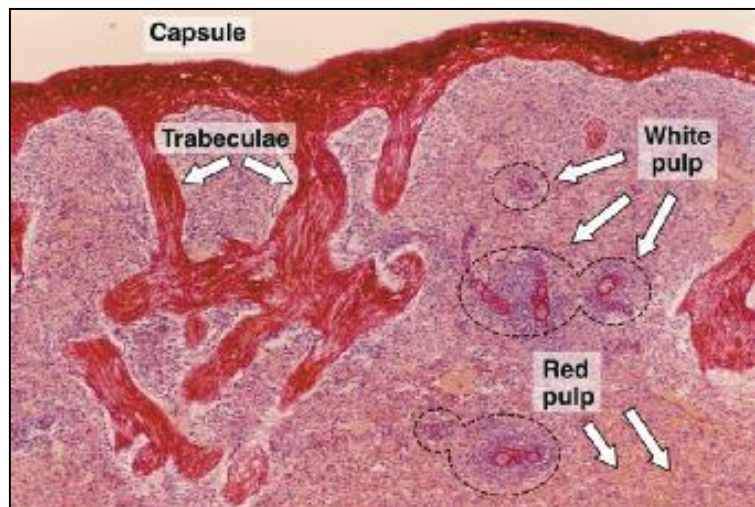
Structure of spleen: Spleen is formed of stroma and parenchyma

- Spleen has a discrete **CT stroma** in the form of capsule which sends septa or trabeculae deep into the volume of the organ. The capsule is formed of collagen with some elastic fibers.
- Between the trabeculae, there is a network of reticular fibers and reticular cells that form the framework of the spleen. The meshes of this network hold cells of splenic parenchyma.
- **Parenchyma** of spleen is formed of splenic pulps (red pulps and white pulps).
 - o **Red pulp** consists of splenic cords separated by blood sinusoids. The red pulp is made up of a mesh of leaky sinusoids through which the red cells are squeezed. Many of the cells lining

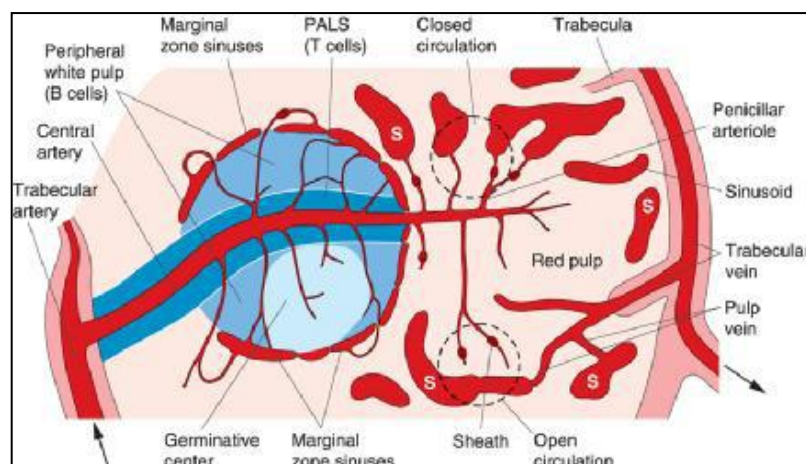
the sinusoids are phagocytic and are able to engulf debris from the blood or fragments of broken red cells.

- **Splenic cords (Cords of Billroth):** Formed of loose meshwork of reticular fibers and reticular cells. The meshwork holds cellular elements of the parenchyma such as T- and B-lymphocytes, plasma cells, and blood cells.
- **Splenic sinusoids:** Vary in shape and size, and are lined by elongated endothelial cells. The sinusoidal wall is leaky, with incomplete basement membrane and lack muscular wall.

Structure of splenic parenchyma, showing the capsule, trabeculae, white and red pulps.



o **White pulp:** Splenic artery penetrates the hilum, branched to give trabecular arteries that leave the trabeculae and enter parenchyma, of spleen. The arteries then surrounded by sheath of lymphocytes called peri-arterial lymphatic sheath (PALS). The sheath contains mainly T-lymphocytes (thymus dependent zone), whereas the lymphoid follicles contain B-lymphocytes.



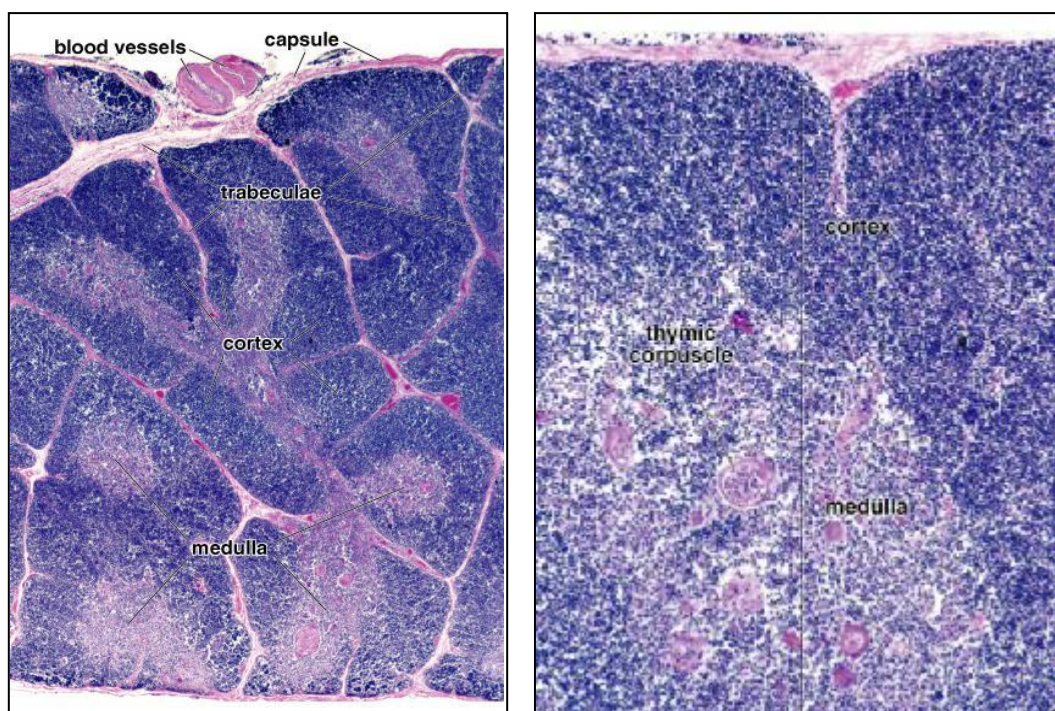
Splenic circulation

Function of spleen:

- Filtration of blood from foreign materials.
- Disposal of defective blood cells
- Spleen is involved in recycling of iron in the body.
- Spleen acts as a reservoir of red blood cells.
- Spleen acts as a hemopoietic organ during embryonic life.
- Spleen has an immunological response; which contain large number of B- and T- lymphocytes that play an important role in defense mechanism.

Thymus gland

The thymus is a primary lymphatic organ, present in the superior mediastinum and it is formed of two lobes. Its presence is required for the immune response to be fully established. The thymus gland reaches maturity during childhood and become rudimentary later on at puberty. Although the thymus is packed with lymphocytes, it does not filter lymph.



Structure of the Thymus gland showing incomplete lobule composed of the cortex and medulla. Medulla looked lighter than the cortex and contain thymic or Hassell's corpuscles

Structure of thymus gland: Thymus gland is formed of stroma and parenchyma

- Thymus is covered with thick connective tissue capsule that sends septa into the two lobes which dividing them into incomplete lobules.

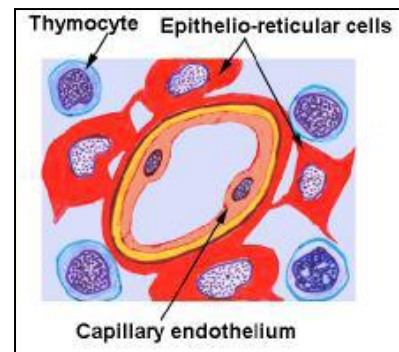
- Each lobule is divided into peripheral dark stained cortex and central pale stained medulla.
- The stroma is formed of reticuloepithelial network that hold lymphocytes.

- Cortex:

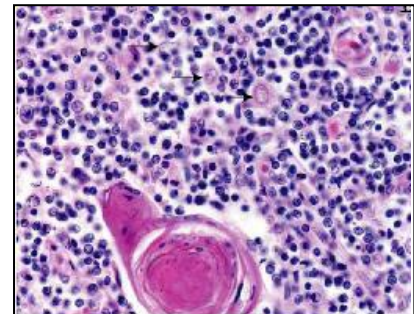
- It is much darker than medulla because of the presence of large number of T-lymphocytes or thymocytes.
- Cortex is the site of T-lymphocytes maturation.
- The cortex contains also macrophage, and reticuloepithelial cells.
- Reticuloepithelium are stellate cells with pale nuclei and long cytoplasmic processes that join together and completely isolate the cortex from the medulla, and are divided into three types; type I, type II, and type III.

- Medulla

- It is much lighter than the cortex because of lymphocytes are less abundant than the cortex, and contain large number of reticuloepithelial cells.



- It contains spherical acidophilic structure called thymic or **Hassell's corpuscles**, which is found only in the medulla, and appears to be degenerating reticuloepithelial cells. It contains also non-fenestrated blood capillaries that form the thymic barriers.



- The reticuloepithelial cells are responsible for the secretion of factors which promote the maturation of the T cells. As the cells mature they are pushed in towards the medulla, where they enter the blood vessels.

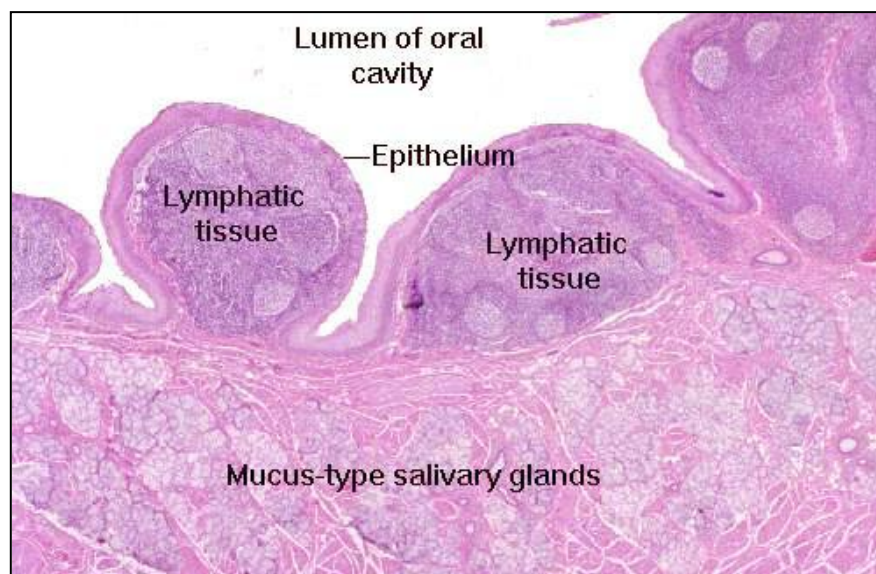
Blood thymic barrier: The blood thymus barrier, a continuous endothelium (non-fenestrated), prevents blood borne antigens from reaching the cortex. The capillaries of the medulla are fenestrated and allow T- cells to enter the circulation.

Function of the thymus gland:

- Thymus gland is essential for T-lymphocyte maturation.
- Reticuloepithelial cells act as endocrine gland that secrete different hormones required for T-cell maturation such as; thymosin, thymopoietin, thymolin, and thymic humoral factor.

Diffuse lymphoid tissues**Tonsils**

Tonsils are found in association with the oral cavity, and can easily be identified by their surface covering of folding mucous membrane (stratified squamous epithelium) with deep crypts between these folds, and lymphoid tissue filling the spaces between them. Tonsils are usually well encapsulated by CT on the side away from the oral cavity; germinal centers are normally present in the lymphoid follicles. Small mucus salivary glands are present below the lymphatic tissue and their ducts open onto the surface of the tonsil. The tonsils contain lymphocytes, macrophages and plasma cells.

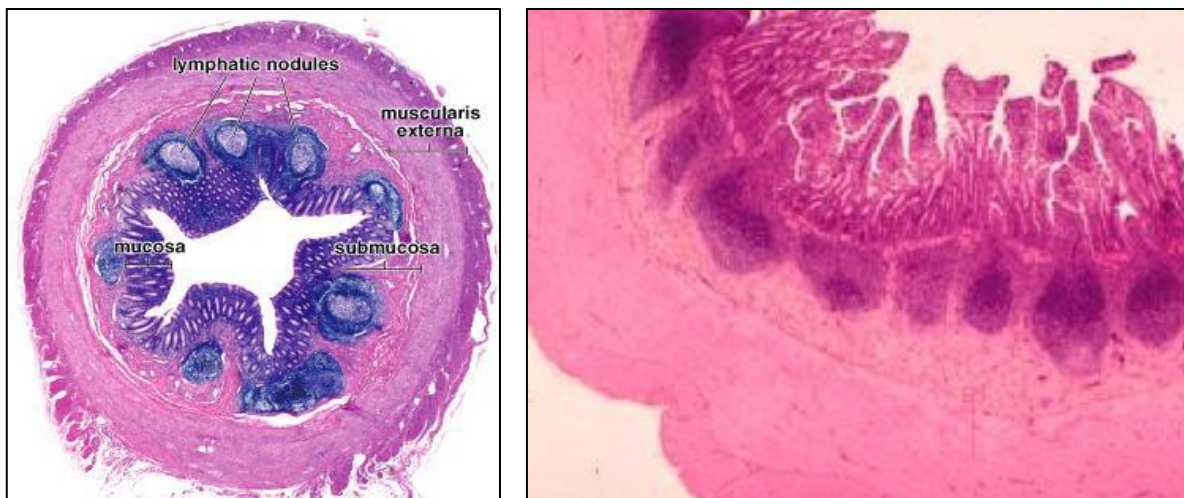


Structure of the tonsils

Aggregated Lymphatic Nodules of the Ileum and Appendix

These structures are large enough to be visible with the naked eye as whitish areas on that side of the intestine opposite to its mesenteric attachment. These lymphoid follicles have germinal centers, the site of maturation and development of the B-lymphocytes.

This cross section of the ileum nicely displays the aggregated lymphatic nodules (still universally called "Peyer's Patches" despite the official nomenclature rules against eponyms). These are the sites of maturation and development of B-lymphocytes. They're very prominent structures in most species. It's quite common to find germinal centers in them, though as the animal ages the number of germinal centers decreases. In cattle, for example, germinal centers are present at the time of birth and they decline relatively rapidly with age, as the pool of "memory" lymphocytes increases.



The Concept of the GALT

Tonsils and Peyer's patches, along with all the diffuse lymphatic tissue in the gastrointestinal tract and respiratory system, collectively are labeled **Gut Associated Lymphatic Tissue (GALT)** or **Mucus Associated Lymphatic Tissue (MALT)**.