

SH Lecture - Lymphatic Structure and Organs




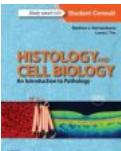
Introduction



(/embryology/index.php/File:SHsmall.jpg) This lecture will provide an overview of the lymphoid structure and histology of key cells, vessels, structures and organs lymphoid organs, including the lymph nodes, spleen and thymus, as well as extranodal lymphoid tissues including mucosa associated lymphoid tissues (MALT).

In this lecture I will go through the structures in sequence from cells through to organs, immunity itself is covered in detail elsewhere in the course.

2018 Lecture - Lecture PDF (/embryology/images/9/9f/2018_SH_Lecture_-_Lymphatic_Structure_and_Organs.pdf)

Textbook References	[Collapse]
<p>Hill, M.A. (2019). <i>UNSW Embryology</i> (19th ed.) Retrieved February 17, 2019, from https://embryology.med.unsw.edu.au (https://embryology.med.unsw.edu.au)</p> <ul style="list-style-type: none">PDF Lecture 2018 (/embryology/images/9/9f/2018_SH_Lecture_-_Lymphatic_Structure_and_Organs.pdf)SH Laboratory Support (/embryology/index.php/SH_Practical_-_Lymphatic_Structure_and_Organs) Movie - AIDS related lymphoma (/embryology/images/4/46/AIDS_related_lymphoma_movie.mp4) Lymphatic Quiz (/embryology/index.php/SH_Practical_-_Lymphatic_Quiz) <p> (/embryology/index.php/File:Moodle_icon2.jpg) Virtual Slides - Lymphatic (http://moodle.telt.unsw.edu.au/mod/book/view.php?id=828270): Human Blood Smear (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=794799) Bone Marrow Smear (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=802056) Thymus (infant) (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=804049) Thymus (adult 1) (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=794807) Thymus (adult 2) (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=802962) Spleen (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=804048) Spleen (silver stain) (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=804648) Lymph Node (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=804046) Lymph Node (silver stain) (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=804042) Lingual tonsil (tongue) (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=804051) Pharyngeal tonsil (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=804050) Appendix (http://moodle.telt.unsw.edu.au/mod/lti/view.php?id=804637) (slide access requires Zpass login)Additional background information:<p>Immune Links (/embryology/index.php/Immune_System_Development): immune (/embryology/index.php/Immune_System_Development) blood (/embryology/index.php/Cardiovascular_System_-_Blood_Development) spleen (/embryology/index.php/Cardiovascular_System_-_Spleen_Development) thymus (/embryology/index.php/Thymus_Development) Lymphatic (/embryology/index.php/Cardiovascular_System_-_Lymphatic_Development) lymph node (/embryology/index.php/Lymph_Node_Development) Antibody (/embryology/index.php/Immune_System_-_Antibody_Development) Med Lecture - Lymphatic Structure Med Practical (/embryology/index.php/SH_Practical_-_Lymphatic_Structure_and_Organs) Immune Movies (/embryology/index.php/Movies#Mouse_Immune) vaccination (/embryology/index.php/Postnatal_-_Vaccination) bacterial infection (/embryology/index.php/Abnormal_Development_-_Bacterial_Infection) Abnormalities (/embryology/index.php/Immune_System_-_Abnormalities) Category:Immune (/embryology/index.php/Category:Immune)</p><div>Historic Embryology (/embryology/index.php/Embryology_History) [Expand]</div></p>	
<p>Janeway's Immunobiology (see in additional information (/embryology/index.php/SH_Lecture_-_Lymphatic_Structure_and_Organs#Additional_Information)) NCBI Bookshelf (http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=imm.TOC&depth=2) A good detailed textbook on the lymphatic system.</p> <p>Nature Immunology - These are short (5-10 min) animations showing how the immune system monitors the epithelial and environment interface at different anatomical locations.</p> <ul style="list-style-type: none">Immunology of the skin (https://youtu.be/_VhcZTGv0CU)Immunology of the lung (https://youtu.be/rghaHmAC_A)Immunology in the gut mucosa (https://youtu.be/gnZEge78_78) <div> Kierszenbaum, A. L., & Tres, L. L. (2012). <i>Histology and cell biology: An introduction to pathology</i>. Philadelphia, PA: Elsevier Saunders. UNSW Students have online access to the current 3rd edn. through the UNSW Library subscription (https://ebookcentral-proquest-com.wwwproxy1.library.unsw.edu.au/lib/unsw/detail.action?docID=1430108).</div> <ul style="list-style-type: none">Chapter 6. Blood And Hematopoiesis (https://ebookcentral-proquest-com.wwwproxy1.library.unsw.edu.au/lib/unsw/reader.action?docID=1430108&ppg=186)Chapter 10. Immune-Lymphatic System (https://ebookcentral-proquest-com.wwwproxy1.library.unsw.edu.au/lib/unsw/reader.action?docID=1430108&ppg=320)<ul style="list-style-type: none">Lymph Node (https://ebookcentral-proquest-com.wwwproxy1.library.unsw.edu.au/lib/unsw/reader.action?docID=1430108&ppg=335)Thymus (https://ebookcentral-proquest-com.wwwproxy1.library.unsw.edu.au/lib/unsw/reader.action?docID=1430108&ppg=339)Spleen (https://ebookcentral-proquest-com.wwwproxy1.library.unsw.edu.au/lib/unsw/reader.action?docID=1430108&ppg=345)Chapter 16. Lower Digestive Segment Protection of the small intestine (https://ebookcentral-proquest-com.wwwproxy1.library.unsw.edu.au/lib/unsw/reader.action?docID=1430108&ppg=501)Blood Chapter Page 169 - Blood development information. Page 191 - Myeloid lineage histology.	

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Lecture
Archive

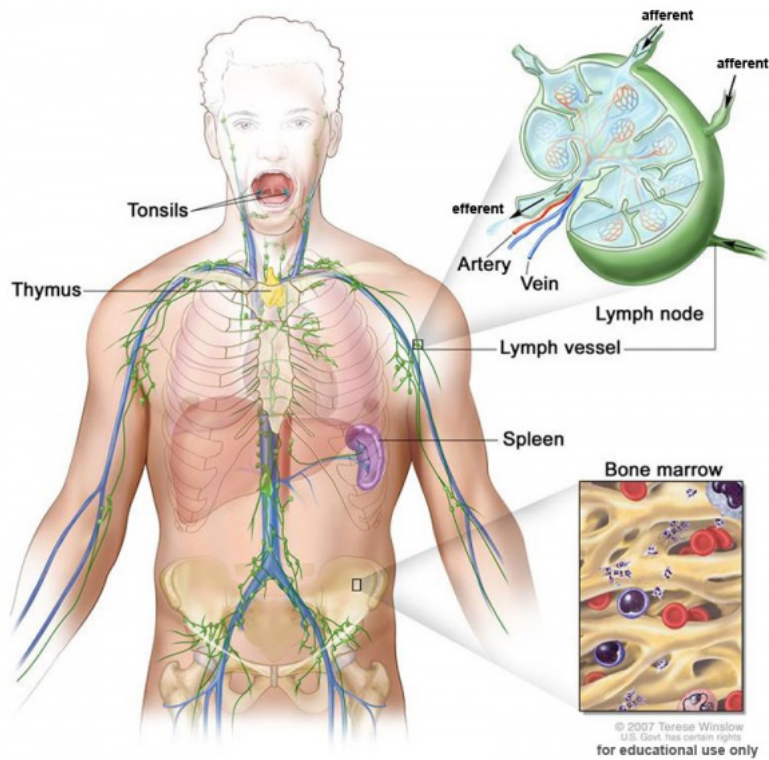
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Structure

1. **Cells** - blood cells (parenchyma), connective tissue (stroma)
2. **Vessels** - lymphatic vessels
3. **Diffuse** - (extra-nodal tissue) nodules, Mucosal Associated Lymphoid Tissues (MALT)
4. **Nodes** - (historic, "glands")
5. **Organs** - thymus, spleen

Function

1. **Immune** - "monitor" of body surfaces, internal fluids
2. **Extracellular fluid** - returns interstitial fluid to circulation
3. **Gastrointestinal tract** - carries fat and fat-soluble vitamins

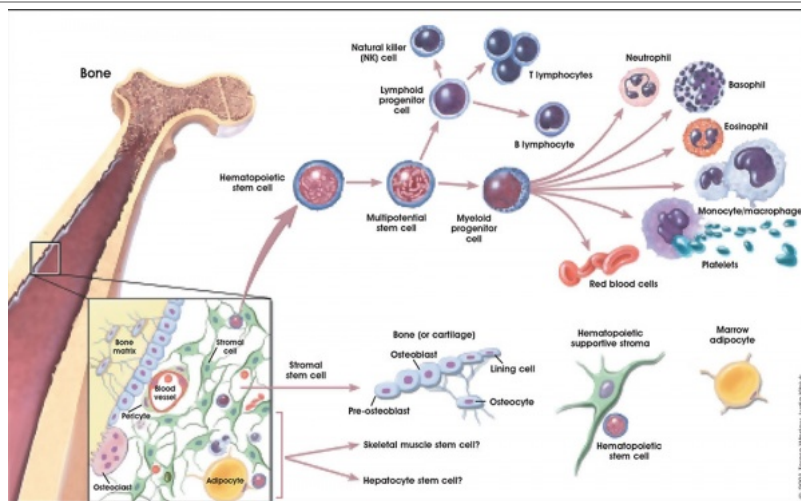


(/embryology/index.php/File:Lymphatic-system-overview.jpg)

Blood Cells

Blood Cell Development

[Colla



(/embryology/index.php/File:Hematopoietic_and_stromal_cell_differentiation.jpg)

Two Blood Cell Systems

1. **Mononuclear Phagocytic System** - circulating monocytes of peripheral blood and non-circulating (fixed) tissue macrophages found throughout the body.
2. **Lymphoid System** - lymphocytes, three major types of T, B, and NK.

Lymphoid Organs

- Central - (primary) Lymphocytes develop from precursor cells in bone marrow and thymus. (see blood marrow image)
- Peripheral - (secondary) Lymphocytes respond to antigen lymph nodes or spleen.

Blood Cells**[Collap**

The blood cell information shown below in the table is shown to identify the relative proportions of different cell types in the circulating blood. This information is provided in the lecture as additional information for reference purposes only.

Blood Cell Numbers

The adult ranges of cells / 1 litre (l), total blood volume is about 4.7 to 5 litres. Blood Development (/embryology/index.php/Cardiovascular_System_-_Blood_Development) | Blood Histology (/embryology/index.php/Template:Blood_Histology)

Red Blood Cells

- Male: $4.32 - 5.66 \times 10^{12}/l$
- Female: $3.88 - 4.99 \times 10^{12}/l$

Leukocytes (white blood cells)

- Male: $3.7 - 9.5 \times 10^9/l$
- Female: $3.9 - 11.1 \times 10^9/l$

Granulocytes

- $1.8 - 8.9 \times 10^9/l$
 - Neutrophils: $1.5 - 7.4 \times 10^9/l$
 - Eosinophils: $0.02 - 0.67 \times 10^9/l$
 - Basophils: $0 - 0.13 \times 10^9/l$

Non-Granulocytes

- **Monocytes** $0.21 - 0.92 \times 10^9/l$

Lymphocytes

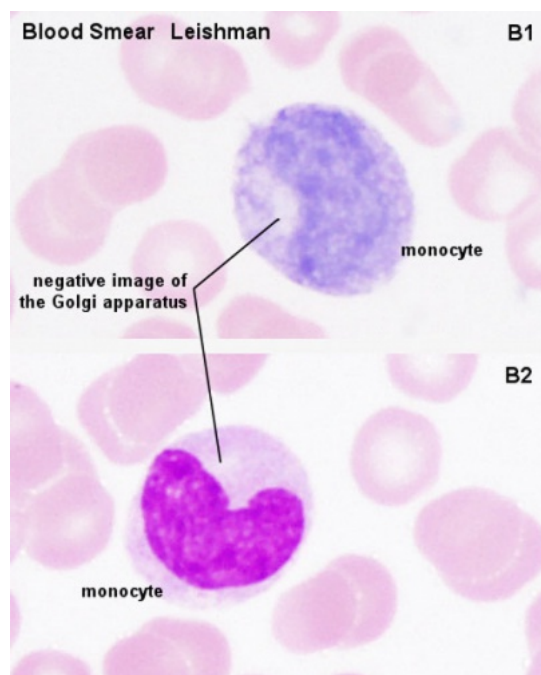
- $1.1 - 3.5 \times 10^9/l$
 - B-cells: $0.06 - 0.66 \times 10^9/l$
 - T-cells: $0.77 - 2.68 \times 10^9/l$
 - CD4+: $0.53 - 1.76 \times 10^9/l$
 - CD8+: $0.30 - 1.03 \times 10^9/l$
 - NK cells: $0.20 - 0.40 \times 10^9/l$

Platelets

- $140 - 440 \times 10^9/l$
 - not a cell, a cell fragment.

1. Mononuclear Phagocytic System**[Colla**

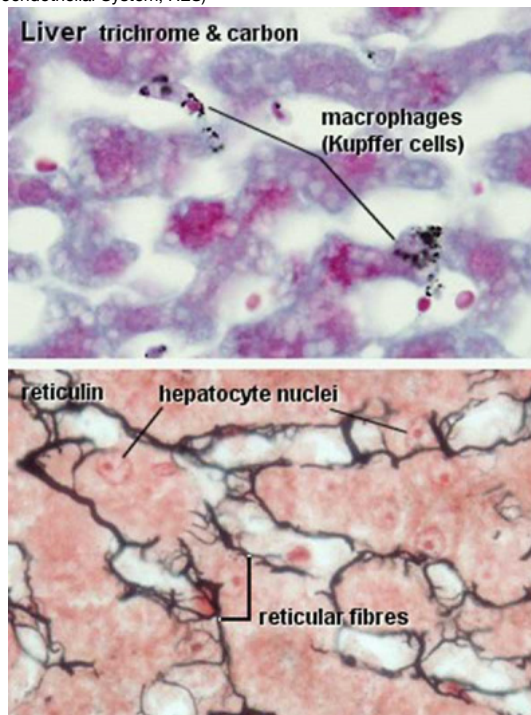
Mononuclear Phagocytic System (MPS, also called Lymphoreticular System or Reticuloendothelial System, RES)



(/embryology/index.php/File:Monocyte_01.jpg)

Circulating **monocytes** of peripheral blood.

- monocytes entering the connective tissue differentiate into **macrophages**



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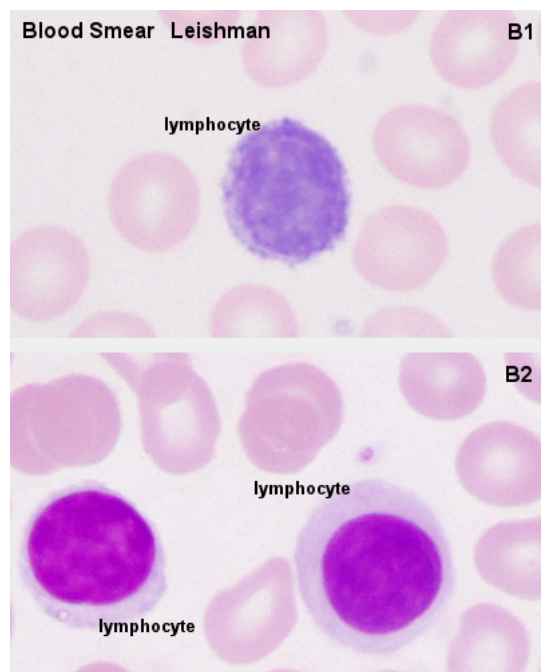
_Kupffer_cell_and_reticular_fibre.jpg)

Non-circulating (fixed) tissue **macrophages** (MΦ)

- found throughout the body (Liver, Kupffer cells (/embryology/index.php/File:Liver_structure_cartoon.jpg)), spleen, nodes and other tissues.

2. Lymphoid System**[Colla**Adaptive immunity functional cells are the **lymphocytes** (B, T, NK) and **dendritic cells** (process antigen and present it on their surface, monocyte precursor derived).

1. **Antibody-mediated** - B Lymphocyte (B cell) when secreting antibody = **plasma cell** - develop in bone marrow
2. **Cell-mediated** - T Lymphocytes (T cell) form **memory cell**, Cytotoxic T cells, T helper cell - develop in thymus

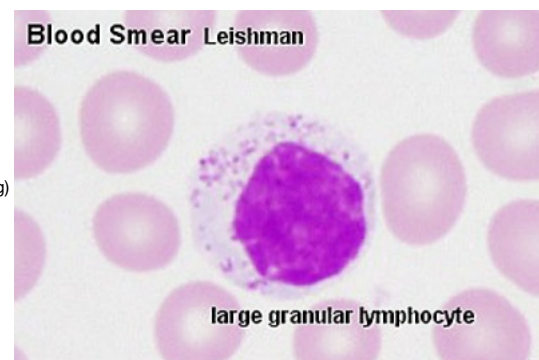


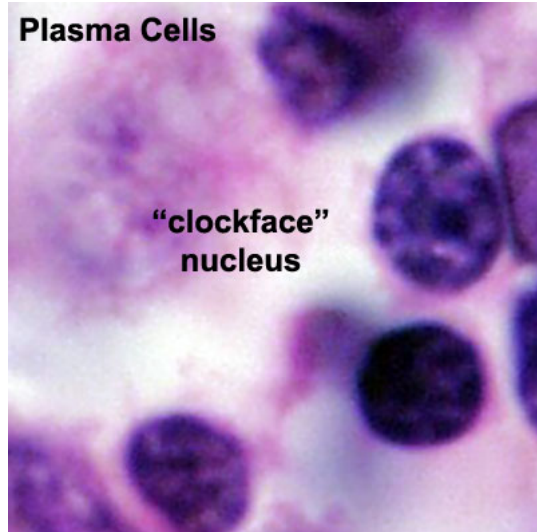
(/embryology/index.php/File:Lymphocyte_01.jpg)

(/embryology/index.php/File:Lymphocyte_02.jpg)

B Cell Development**Germinal Centres**

- Bone marrow
- blood
- Lymph node, nodule
- Lymphatic vessel
- Bone marrow
- Bone Marrow
- Medullary cords contain plasma cells

**Plasma cells**



(/embryology/index.php/File:Plasma_cell_clockface_nucleus_01.jpg)

- Activated B cell, plasma B cells, plasmocytes, effector B cells and B cell that is secreting antibody.
- secrete antibody directly into blood for distribution to all body
- in local extrafollicular sites are short lived 2–4 days
- longer-lived plasma cells in bone marrow 3 weeks to 3 months+
- "clockface" nucleus
 - Nucleus has darker (heterochromatin) regions around periphery of nucleus separated by lighter (euchromatin) regions.

Lymphocyte Electron Micrographs [Expand]

Lymphocyte Circulation

- Microbial **antigens** are carried into a lymph node by **dendritic cells**, which enter via afferent lymphatic vessels draining an infected tissue.
- **T and B cells** enter the lymph node via an artery and migrate out of the bloodstream through postcapillary venules.
 - Unless they encounter their antigen, the T and B cells leave the lymph node via efferent lymphatic vessels, which eventually join the thoracic duct.
- The thoracic duct empties into a large vein carrying blood to the heart.
- A typical circulation cycle takes about 12–24 hours.

Links: MBoC Chapter 24 - The Adaptive Immune System (<http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=mboc4&part=A4419>) | MBoC Figure 24-14. The path followed by lymphocyte they continuously circulate between the lymph and blood (<http://www.ncbi.nlm.nih.gov/books/NBK26921/figure/A4442>) | Immunobiology (<http://www.ncbi.nlm.nih.gov/bookshelf/br.fcgi?book=immunobiology>)

Diffuse Lymphatic Tissue

Diffuse Lymphatic Tissue Locations

respiratory passage, alimentary canal, ocular surface, and urogenital tract.

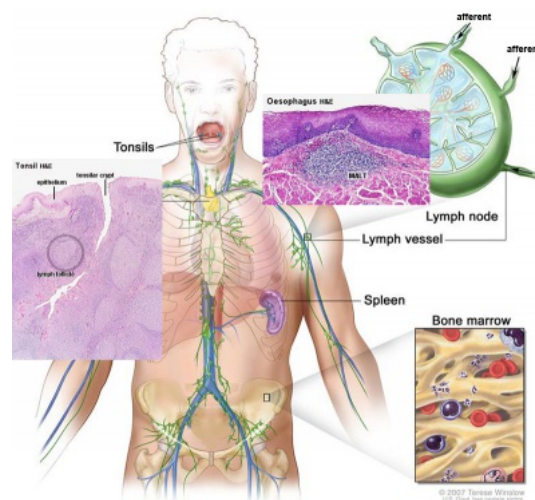
- **MALT - Mucosa Associated Lymphoid Tissue**
 - MALT - initiates immune responses to specific antigens encountered along all mucosal surfaces.
- **NALT - Nasal Associated Lymphoid Tissue**
- **BALT - Bronchus Associated Lymphoid Tissue**
- **GALT - Gut Associated Lymphoid Tissue**
- **Not enclosed by a connective tissue capsule**
- Located in subepithelial tissue - **lamina propria**
- Diffuse lymphatic tissue + nodules
- Reactive - enlarge when activated (by antigen)

Lymphocytes

- travel to nodes and back again
- proliferation and differentiation

Gastrointestinal Tract

- Oropharynx - Tonsils
- Distal small intestine (Ileum) - Peyer's Patches
- Appendix, cecum



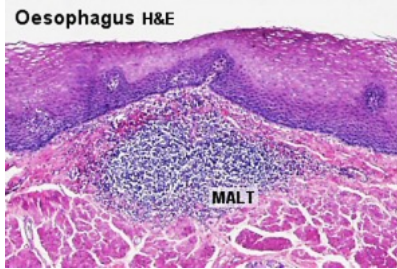
(/embryology/index.php/File:Lymphatic-system-tonsil-MALT.jpg)

Waldeyer's ring - Mucosal Associated Lymphoid Tissue**[Collapse]**

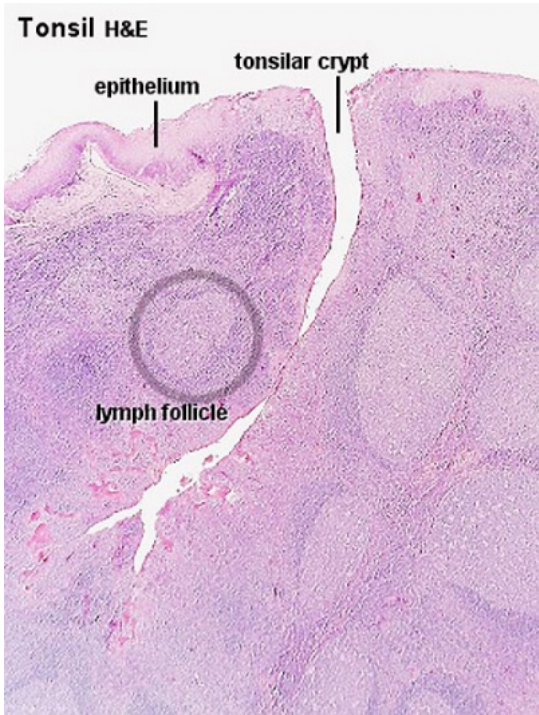
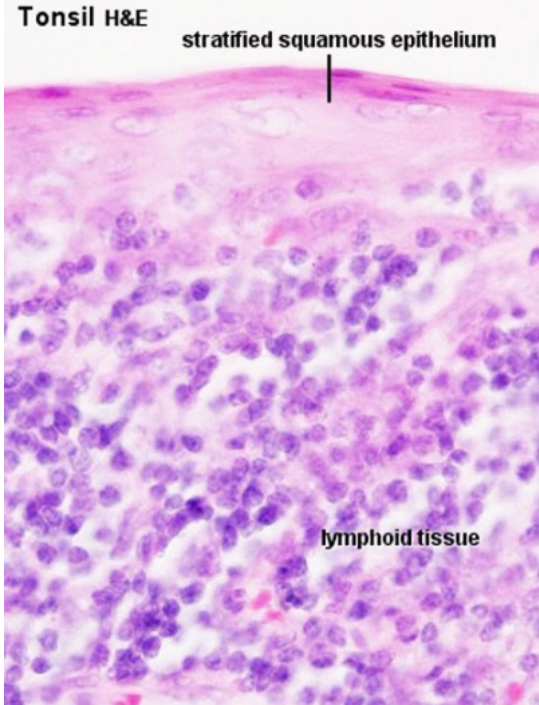
Waldeyer's ring - oral adenoid tissue

Anatomical location - Palatine (**tonsils**), Lingual and Pharyngeal (**adenoids**)

- anterior - **lingual tonsil** formed by the submucous adenoid collections.
- lateral - **palatine tonsils** and adenoid collections near the auditory tubes.
- posterior - **pharyngeal tonsil** on the posterior wall of the pharynx.
- between main masses are smaller collections of adenoid tissue.



(/embryology/index.php/File:Oesophagus_MALT.jpg)

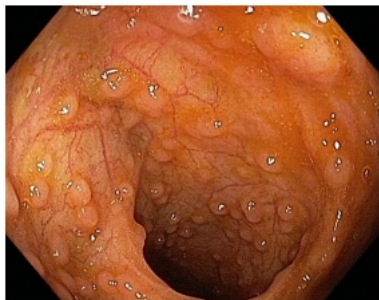
Tonsils		[Colla
<p>Palatine Tonsils</p> <ul style="list-style-type: none"> the "tonsils", lateral wall of oropharynx covered by stratified squamous epithelium numerous crypts (10-20) infolds of surface epithelium Afferent lymph vessels absent Efferent lymph vessels are present PMID 7559106 	 <p>Tonsil H&E</p> <p>epithelium</p> <p>tonsillar crypt</p> <p>lymph follicle</p> <p>(/embryology/index.php/File:Tonsil_histology_01.jpg)</p>	
	 <p>Tonsil H&E</p> <p>stratified squamous epithelium</p> <p>lymphoid tissue</p> <p>(/embryology/index.php/File:Tonsil_histology_02.jpg)</p>	
<p>Lingual Tonsils</p> <ul style="list-style-type: none"> lamina propria root of tongue covered by stratified squamous epithelium salivary glands and skeletal muscle are directly adjacent 	<p>Pharyngeal Tonsils</p> <ul style="list-style-type: none"> adenoids or nasopharyngeal tonsils, upper posterior part of throat covered by a pseudostratified ciliated epithelium with goblet cells 	

Peyer's Patches

Peyer's Patch

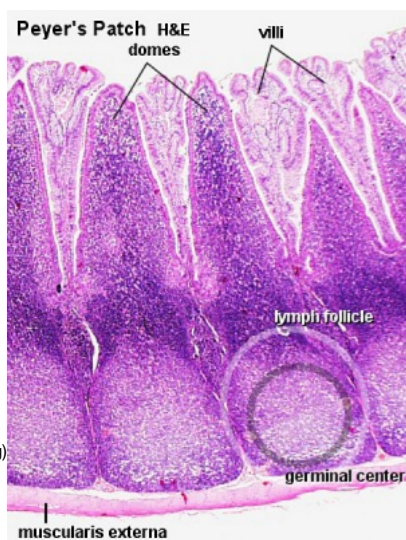
[Collapse]

Located in the ileum



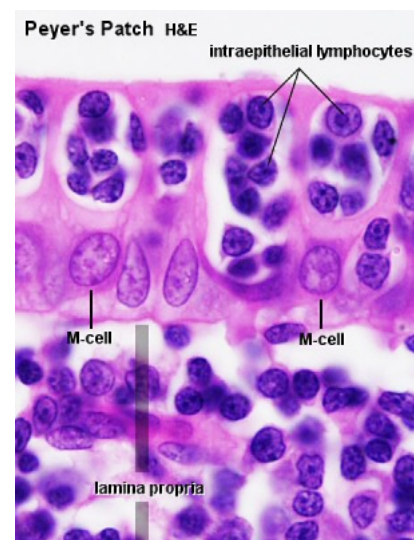
(/embryology/index.php/File:Peyers_patches_ileocolonoscopy_01.jpg)

Peyers patches (ileocolonoscopy)



(/embryology/index.php/File:Peyer%27s_patch_01.jpg)

Peyer's Patch (histology)



(/embryology/index.php/File:Peyer%27s_patch_02.jpg)

microfold cells or M-cells
(transport gut lumen organisms and particles to immune across the epithelial barrier).

About Peyer's Patch

[Collapse]

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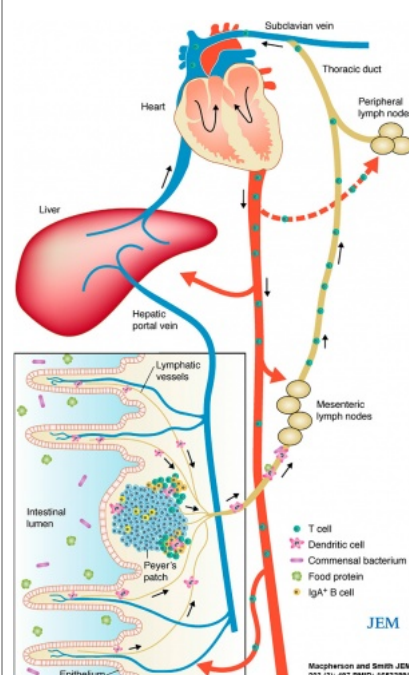
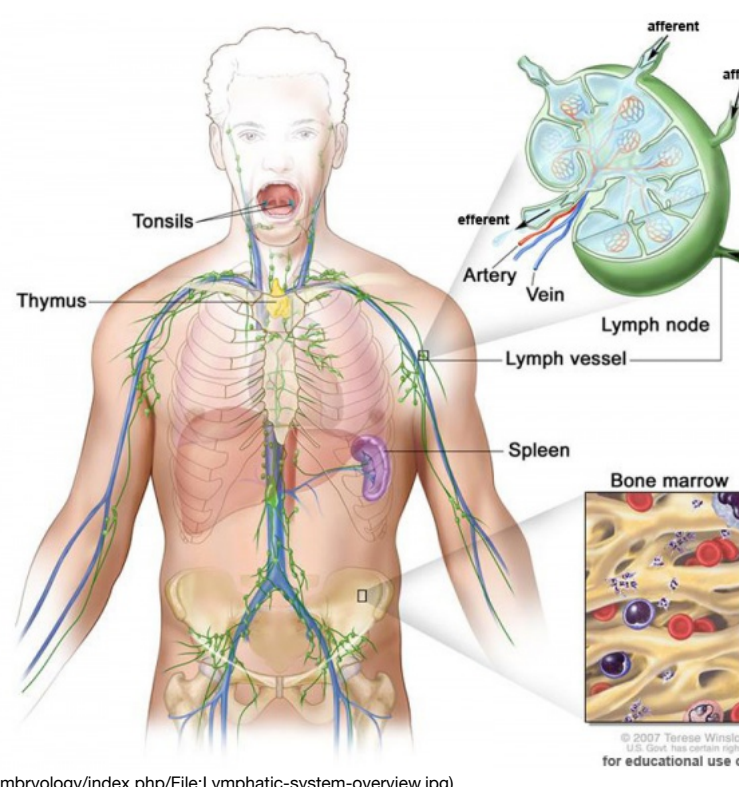
- Peyer's Patches are named after Johann Conrad Peyer (1653 – 1712) a Swiss anatomist who first described these specialised structures.
- Learn how the Peyer's Patches function in the Gut Mucosa immune function in this Nature Immunology Animation - Immunology in the Gut Mucosa (https://youtu.be/gnZEge78_78)

Immunology in the Gut Mucosa

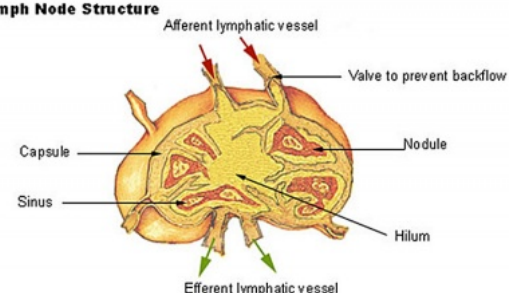


Lymph Nodes

Lymph Node Anatomy

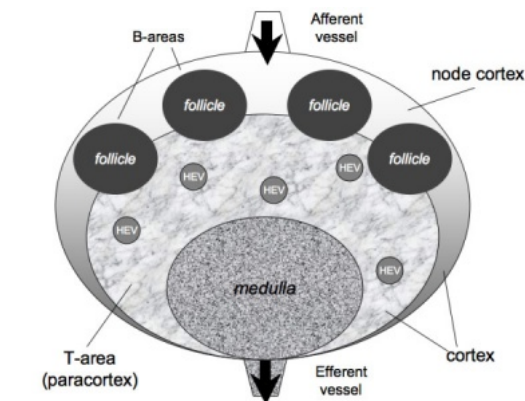
Lymph Node Anatomy [Collapse]	
<ul style="list-style-type: none"> Location throughout the entire body - concentrated in axilla, groin, lung, gastrointestinal tract mesenteries Small (1 mm - 2 cm) encapsulated organ (diffuse lymphoid tissue - no capsule) Antigen transformed lymphocytes from the blood In lymph vessel pathways "filter" lymph <ul style="list-style-type: none"> Afferent - towards node (A - arrives at the node) Efferent - away from node (E - exits the node)  <p>Mesenteric lymph nodes</p> <p>(/embryology/index.php/File:Gastrointestinal_tract_intestine_immune_cartoon_01.jpg)</p>	 <p>(/embryology/index.php/File:Lymphatic-system-overview.jpg)</p>

Lymph Node Functions

Lymph Node Functions	Lymph Node Structure [Collapse]
<ul style="list-style-type: none"> In lymph vessel pathways "filter" (surveillance) lymph Immune - detect infections from peripheral tissues <ul style="list-style-type: none"> skin, respiratory tract, gastrointestinal tract, etc. secondary lymphoid organ return extracellular fluid to circulation 	<p>Lymph Node Structure</p>  <p>(/embryology/index.php/File:Lymph_node_structure.jpg)</p>

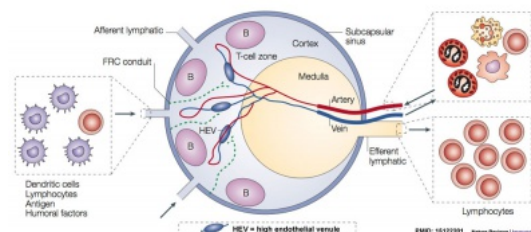
Lymph Node Structure

Lymph Node Structure	[Collapse]



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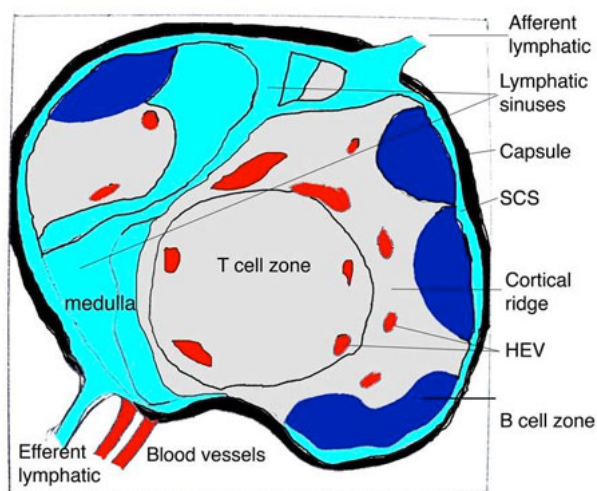
Simplified structure



(/embryology/index.php/File:Lymph_node_cartoon_02.jpg)

Lymphocyte (T and B) Traffic

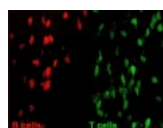
1. Enter from high endothelial venules (HEVs also called post-capillary venules)
2. Spend 8 to 24 h in the lymph node interstitium.
3. Enter a network of medullary sinuses.
4. Drain from sinuses into efferent lymphatic vessels.



Lymph pathway

1. Afferent vessel
2. Subcapsular sinus
3. Paratrabeular sinus
4. Medullary sinus
5. Efferent vessel

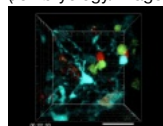
Watch T and B Lymphocytes Move



(/embryology/index.php/Mouse_Lymph_Node_Movie_7)

Lymph Node 7

Page (/embryology/index.php/Mouse_Lymph_Node_Movie_7) | Play
(/embryology/images/0/0c/Mouse_adult_lymph_node_07.mp4)



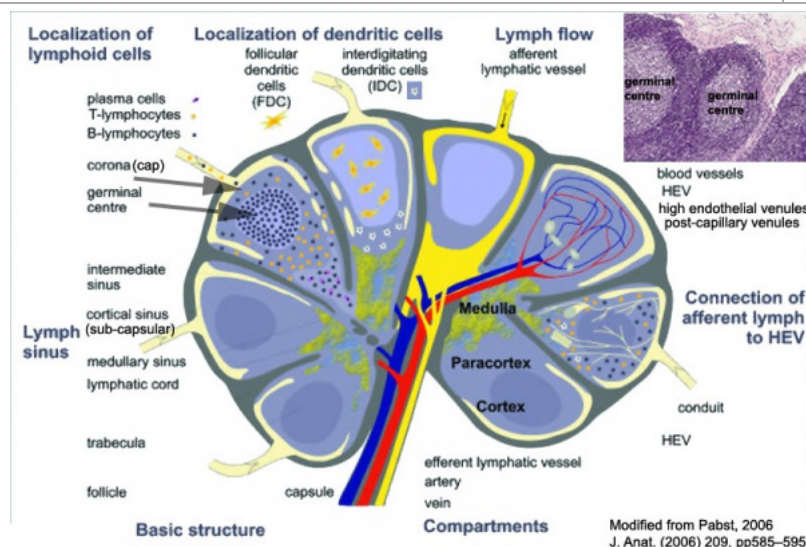
(/embryology/index.php/Mouse_Lymph_Node_Movie_8)

Lymph Node 8

Page (/embryology/index.php/Mouse_Lymph_Node_Movie_8) | Play
(/embryology/images/4/42/Mouse_adult_lymph_node_08.mp4)

Lymph Node

(/embryology/index.php/File:Lymph_node_structure_02.jpg)

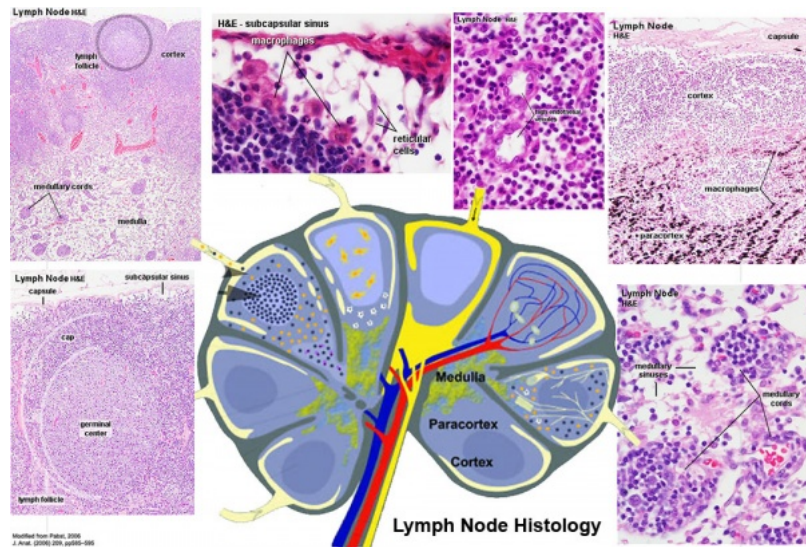


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Lymph Node Histology

Lymph Node Histology

[Colla

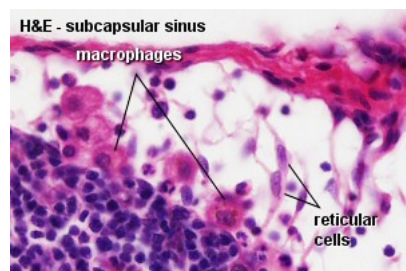


(/embryology/index.php/File:Lymph_node_cartoon_03.jpg)

Connective Tissue

- **Capsule** - dense connective tissue (irregular CT, some adipocytes)
- **Trabeculae** - dense connective tissue
- **Reticular Tissue** - Reticular cells and fibers, supporting meshwork (collagen type III)
 - Reticular cell produces reticular fibers (**collagen type III**) and surrounds the fibers with its cytoplasm
 - reticular fibres can also be produced by fibroblasts

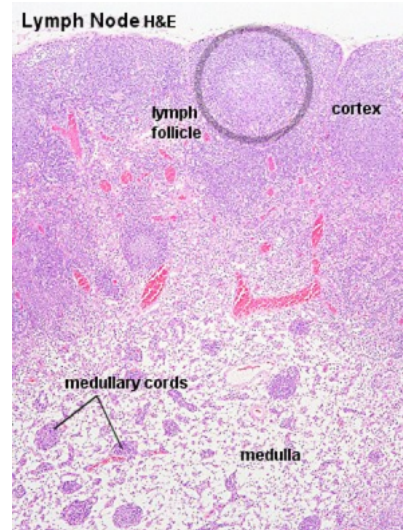
Subcapsular Sinus



(/embryology/index.php/File:Lymph_node_histology_01.jpg)

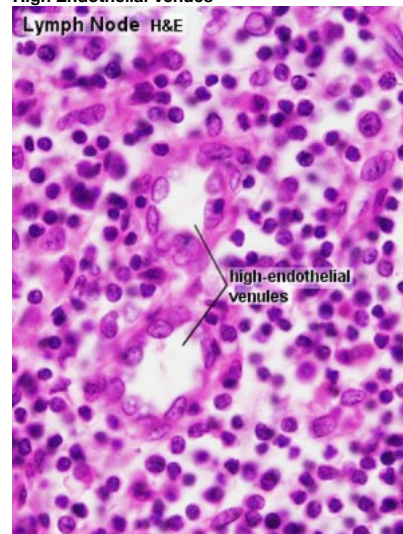
(marginal sinus, continuation of trabecular sinus)

Follicle



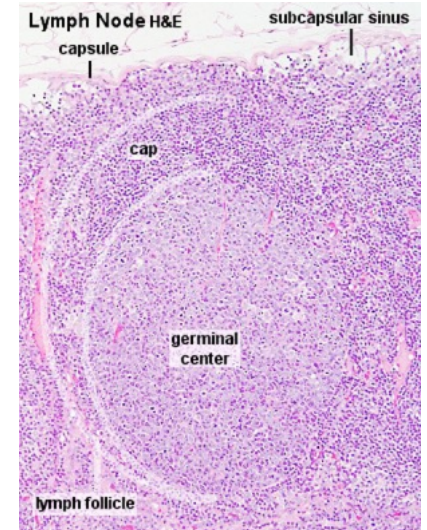
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High Endothelial Venues



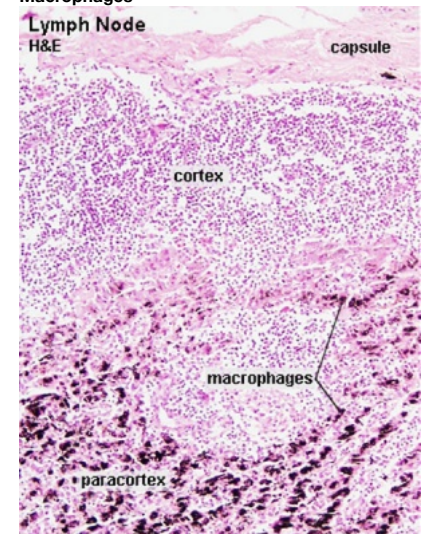
(/embryology/index.php/File:Lymph_node_histology_05.jpg)

Germinal Centre



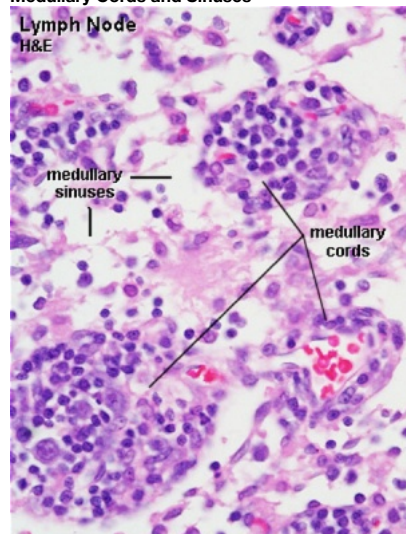
(/embryology/index.php/File:Lymph_node_histology_03.jpg)

Macrophages



(/embryology/index.php/File:Lymph_node_histology_06.jpg)

Medullary Cords and Sinuses



(/embryology/index.php/File:Lymph_node_histology_04.jpg)

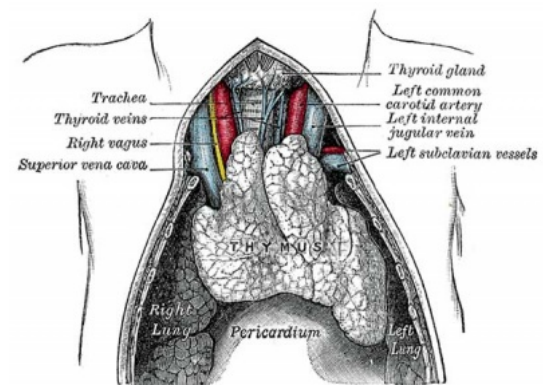
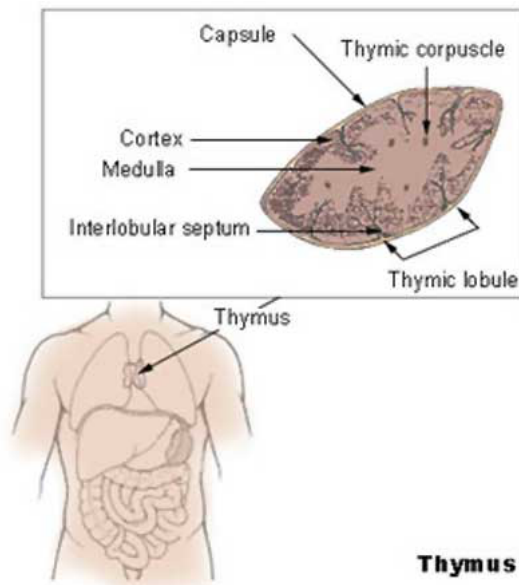
Lymph Node Cartoons (/embryology/index.php/Lymph_Node_Development): Detailed structure (/embryology/index.php/File:Lymph_node_cartoon_01.jpg) | Cartoon with Histology (/embryology/index.php/File:Lymph_node_cartoon_03.jpg) | Lymphocyte traffic (/embryology/index.php/File:Lymph_node_cartoon_02.jpg) | Simple structure (/embryology/index.php/File:Lymph_node_structure.jpg) | Wiki node image (/embryology/index.php/File:Lymph_node_structure_01.png) | Internal structure (/embryology/index.php/File:Lymph_node_structure_02.jpg) | Mesenteric lymph node (/embryology/index.php/File:Gastrointestinal_tract_intestine_immune_cartoon_01.jpg) | Histology (/embryology/index.php/Lymph_Node_Development#Histology) | Gallery (/embryology/index.php/Lymph_Node_Development#Lymph_Node_Cartoon_Gallery) | Lymph Node Development (/embryology/index.php/Lymph_Node_Development)

Links: Immunobiology - Figure 1.8. Organization of a lymph node (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A47>) | Figure - Germinal centre development in lymph nodes (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4399774/figure/F1/>)

Thymus

Thymus Anatomy

Thymus Anatomy

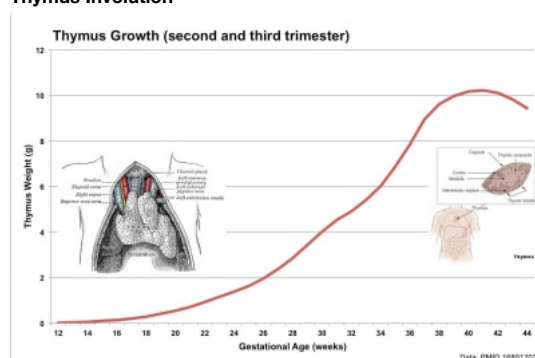


(/embryology/index.php/File:Gray1178.jpg)

(/embryology/index.php/File:Thymus_cartoon.jpg)

adult thymus - bilobed, superior mediastinum, anterior to heart

Thymus Involution



(/embryology/index.php/File:Fetal_thymus_weight_growth_graph.jpg)

infant thymus - large

Overall Size Changes with age

- birth 10-15 g
- puberty 30-40 g
- after puberty - involution
 - replaced by adipose tissue
- middle-aged 10 g

Thymus Functions

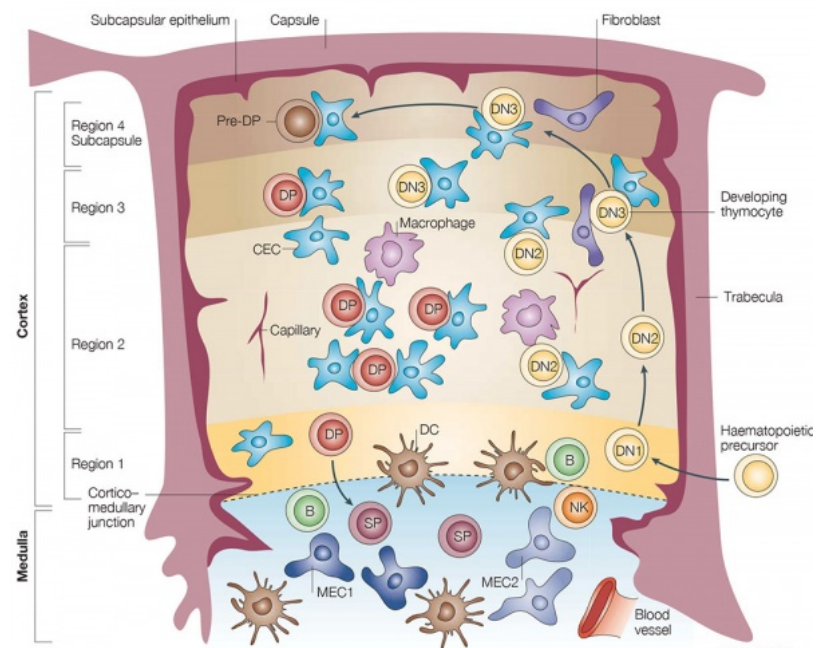
Thymus Functions

[Colle

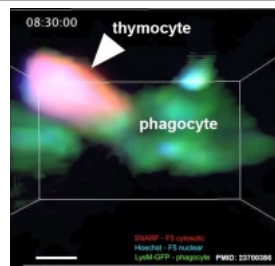
- specialised thymus microenvironments allow the production of self-tolerant T-cells (T lymphocytes) from immature precursors.
 - immature precursors enter the thymus
 - differentiate and undergo selection by thymic epithelial cell (TEC) subtypes
 - mature release into circulation of these cells
- destruction of cells that recognise self antigens
- T-cells kill infected and oncogenic cells

T Cells maturation within the thymus

- T cell progenitors** enter the thymus at the cortex/medulla border via post-capillary venules
- migrate** toward the capsule in response to chemokine signalling.
- cortex** - thymocytes undergo positive selection by cTECs then migrate to the medulla
- medulla** - thymocytes are screened for reactivity to tissue-restricted self antigens expressed by mTECs.
- Mature T cells** exit the thymus via blood or lymphatic vessels in response to a sphingosine-1-phosphate (S1P) gradient.



(/embryology/index.php/File:Thymus_structure_and_function_cartoon01.jpg)



(/embryology/index.php/File:Mouse_adult_thymus_11.jpg)

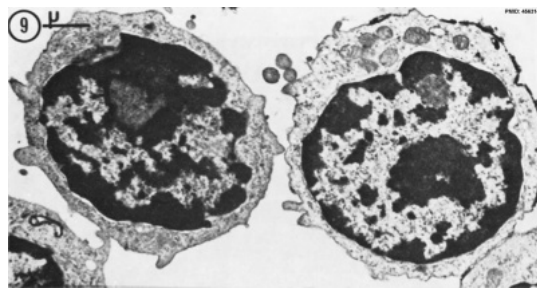
Macrophages phagocytosis of T cells



(/embryology/index.php/Mouse_Thymus_Movie_1)

Thymus 1

Page (/embryology/index.php/Mouse_Thymus_Movie_1) | Play
 (/embryology/images/6/6b/Mouse_adult_thymus_01.mp4)



(/embryology/index.php/File:T_and_B_lymphocytes_EM09.jpg)

EM - T and B lymphocytes (look the same)

Thymus Structure

Thymus Structure

[Colla

Structure Overview

- Connective tissue capsule (thin) with numerous trabeculae (septa)
 - major blood vessels run in CT
- Lobules containing **cortex** and **medulla** regions
 - medullary regions are continuous (connected together)
- NOT supplied by afferent lymph vessels

Blood-Thymic Barrier

- Blood vessels are separated from thymus cortex by epithelioreticular cells.
- impermeable to most macromolecules.
- Barrier layers: capillary endothelium - endothelial basal lamina - perivascular CT sheath - basal lamina of epithelioreticular cells - epithelioreticular cell sheath

Thymus Epithelioreticular cells (TEC)

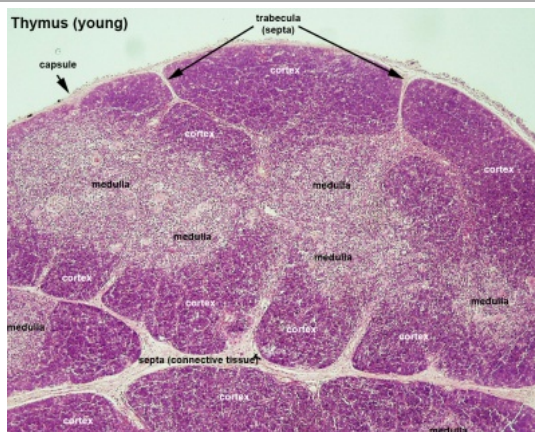
- Abundant, eosinophilic, large, ovoid and light nucleus
- 1-2 nucleoli
- sheathe cortical capillaries
- form an epitheloid layer
- maintain microenvironment for development of T-lymphocytes in cortex (thymic epitheliocytes)

Macrophages

- cortex and medulla
- difficult to distinguish from reticular cells in (Stain - Haematoxylin Eosin (http://embryology.med.unsw.edu.au/embryology/index.php/Histology_Stains#Haematoxylin_and_Eosin))
- remove auto-reactive T-lymphocytes

Lymphocytes

- located in cortex and medulla
- more numerous (denser) in cortex
- majority are developing T-lymphocytes (thymic lymphocytes or thymocytes)

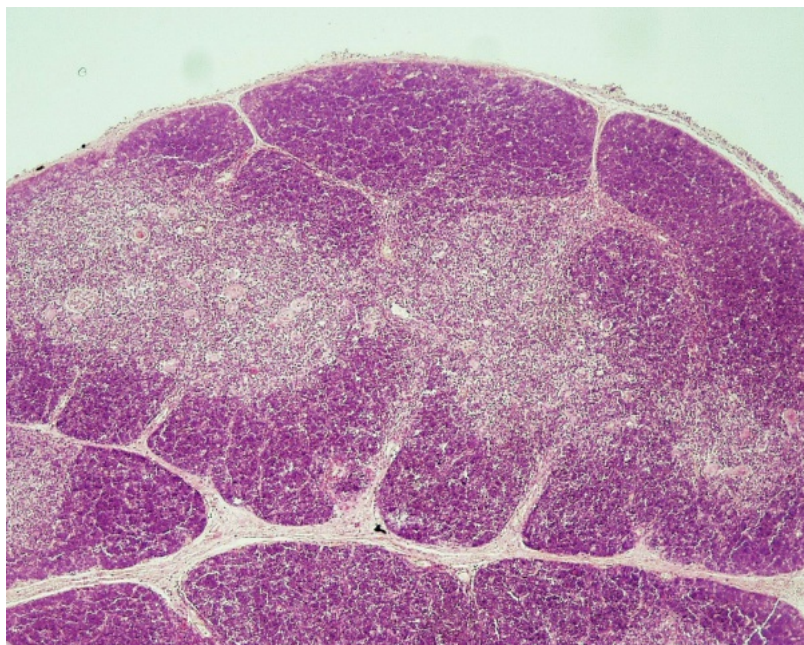

http://embryology.med.unsw.edu.au/embryology/index.php/File:Thymus_histology_01.jpg

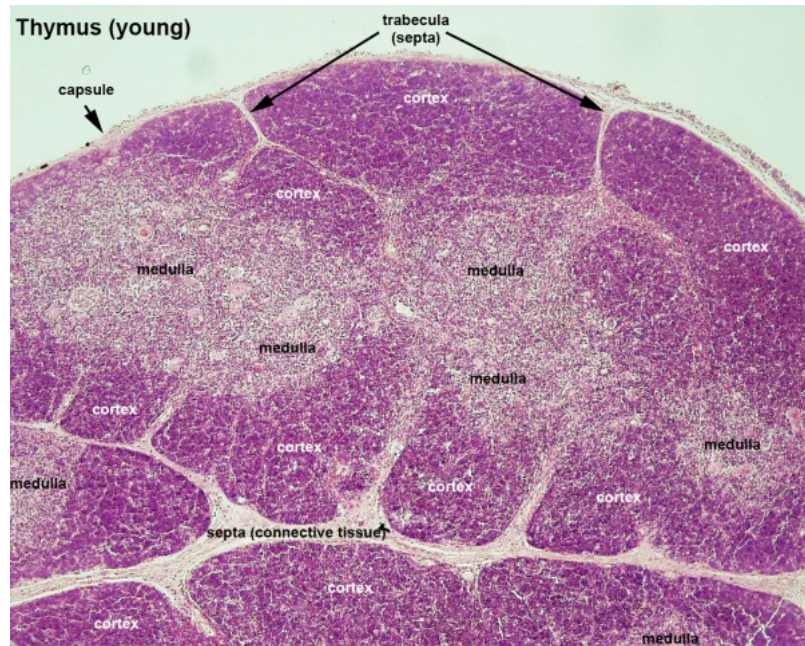
Thymus Histology

Thymus Histology

[Colla

- Capsule (thin) with trabecular or septa (dense connective tissue)

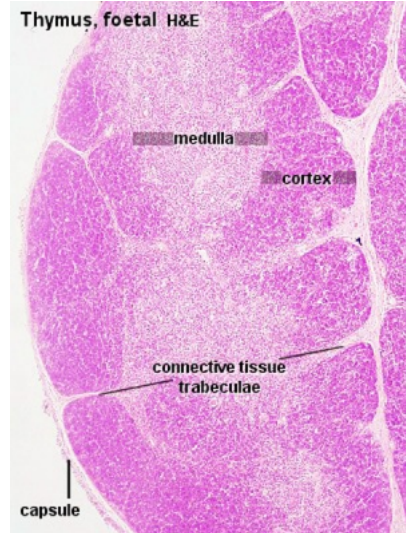

http://embryology.med.unsw.edu.au/embryology/index.php/File:Thymus_histology_01.jpg



(/embryology/index.php/File:Thymus_histology_06.jpg)

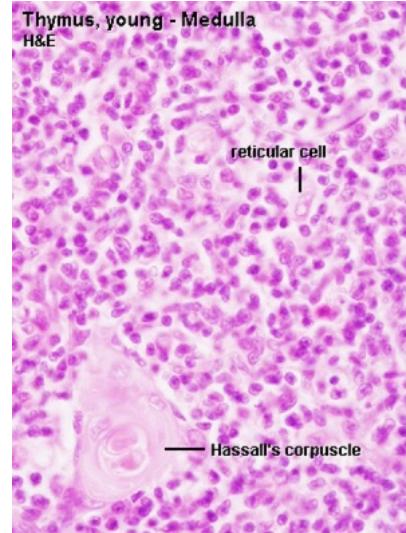
Infant thymus

Fetal thymus



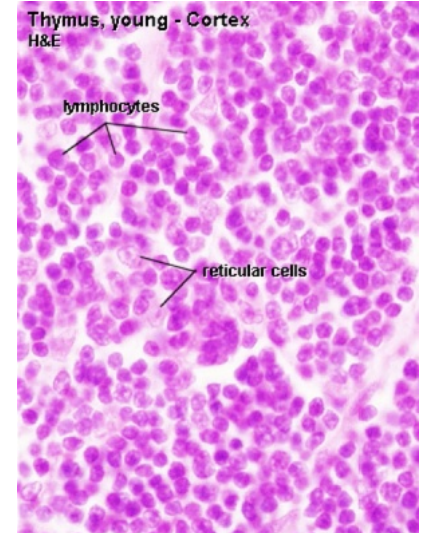
(/embryology/index.php/File:Fetal_thymus.jpg)

Young medulla



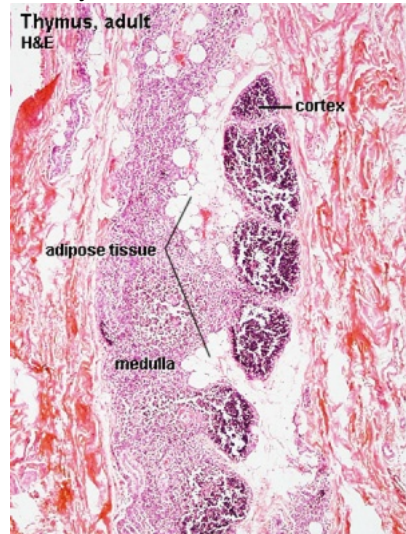
(/embryology/index.php/File:Thymus_-_young_01.jpg)

Young cortex



(/embryology/index.php/File:Thymus_-_young_02.jpg)

Adult Thymus



(/embryology/index.php/File:Thymus_adult.jpg)

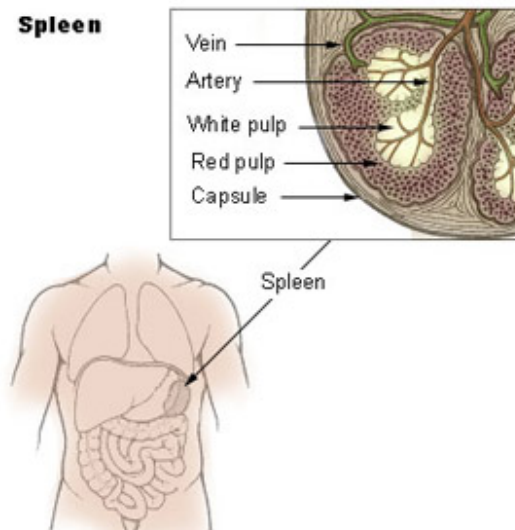
- Cortical lymphoid tissue is replaced by adipose tissue (involution)
- Increase in size of thymic corpuscles
- **Thymic corpuscle** - (Hassall's corpuscle) mass of concentric epithelioreticular cells.

Thymus Histology (/embryology/index.php/Thymus_Development#Histology): Fetal Thymus overview (/embryology/index.php/File:Fetal_thymus.jpg) | Fetal Thymus Medulla (/embryology/index.php/File:Thymus_-_young_01.jpg) | Fetal Thymus Cortex (/embryology/index.php/File:Thymus_-_young_02.jpg) | Adult Thymus (/embryology/index.php/File:Thymus_adult.jpg) | unlabeled fetal overview (/embryology/index.php/File:Thymus_histology_01.jpg) | unlabeled fetal medulla (/embryology/index.php/File:Thymus_histology_02.jpg) | unlabeled fetal thymic corpuscle (/embryology/index.php/File:Thymus_histology_05.jpg) | unlabeled fetal cortex (/embryology/index.php/File:Thymus_histology_03.jpg) | unlabeled adult overview (/embryology/index.php/File:Thymus_histology_04.jpg) | Category:Thymus (/embryology/index.php/Category:Thymus) | Immune System Development (/embryology/index.php/Immune_System_Development)

Spleen

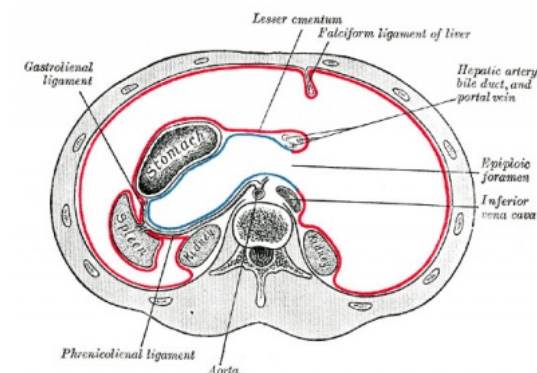
Spleen Anatomy

Spleen Anatomy



(/embryology/index.php/File:Spleen_anatomy.jpg)

left hypochondriac region



(/embryology/index.php/File:Gray1039.jpg)

almost entirely surrounded by peritoneum adherent to its capsule

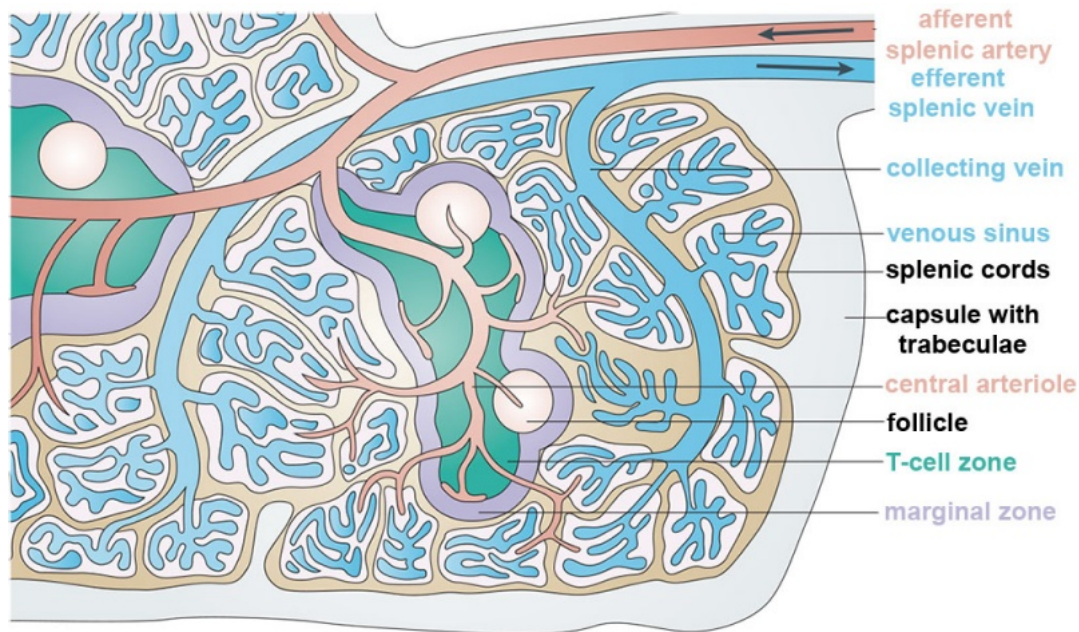
Spleen Functions

Spleen Functions	[Colla
<ol style="list-style-type: none"> Immune - filters blood in much the way that the lymph nodes filter lymph. <ol style="list-style-type: none"> Lymphocytes in the spleen react to pathogens in the blood and attempt to destroy them. Macrophages then engulf the resulting debris, the damaged cells, and the other large particles. Red Blood Cell Removal - spleen (and liver) removes old and damaged erythrocytes from the circulating blood. Blood Reservoir - The sinuses in the spleen also act as a reservoir for blood. In emergencies (haemorrhage) smooth muscle in the vessel walls and in the capsule of the spleen contract squeezes blood out of the spleen into the general circulation. 	

Spleen Structure

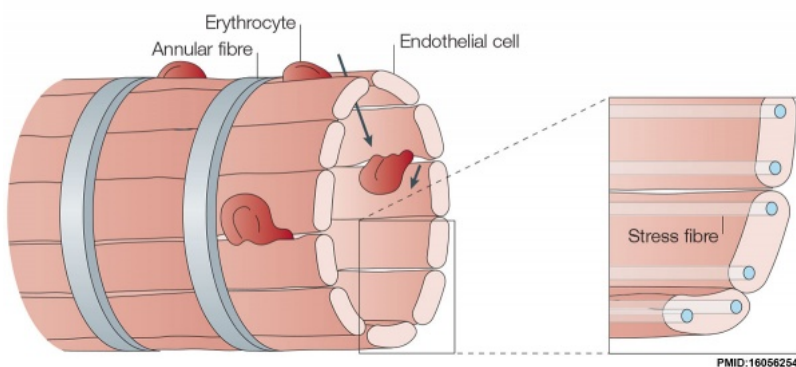
Spleen Structure

[Colla



(/embryology/index.php/File:Spleen_structure_cartoon_01.jpg)

- **afferent splenic artery** branches into central arterioles, which are sheathed by white pulp areas.
- **white pulp** areas consist of the T-cell zone (also known as the periarteriolar lymphoid sheath, PALS), arterioles and B-cell follicles.
- arterioles end in cords in the **red pulp**, from where the blood runs into venous sinuses that collect into the **efferent splenic vein**.
- larger arteries and veins run together in connective-tissue trabeculae, which are continuous with the capsule that surrounds the spleen.



(/embryology/index.php/File:Spleen_structure_cartoon_02.jpg)

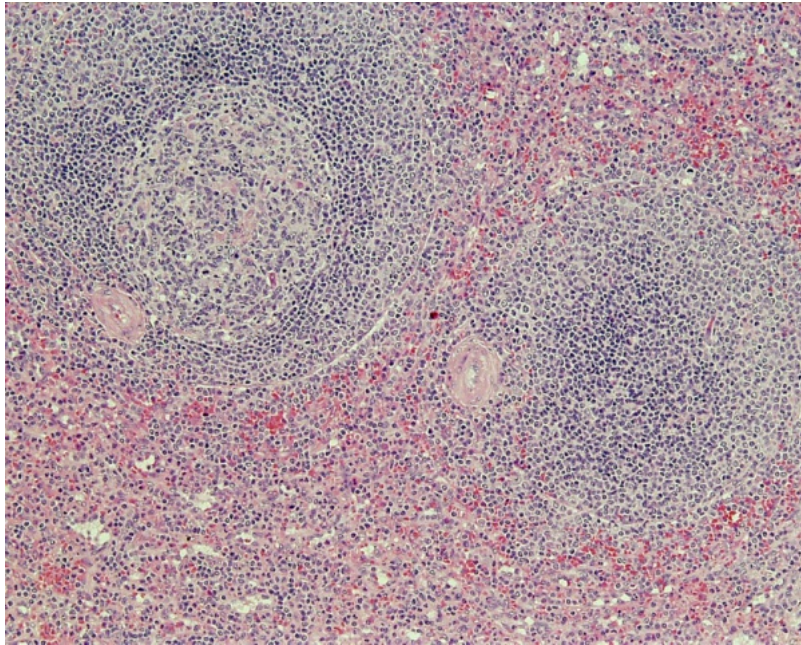
Red pulp

Spleen Histology

Spleen Histology

[Colla

- Capsule with trabeculae (dense connective tissue)
- Reticular fibroblasts - reticular fibres (Type III collagen)



(/embryology/index.php/File:Spleen_histology_06.jpg)

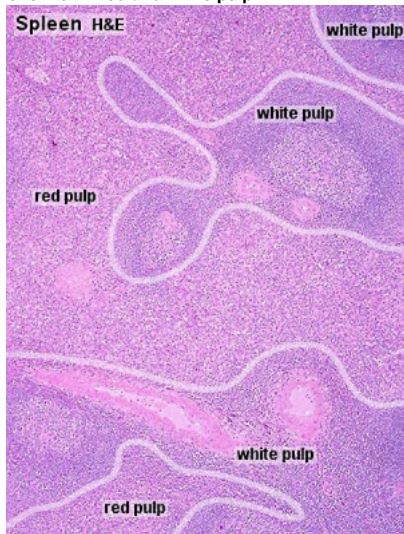
White Pulp

- lymph follicle
- germinal center
- central artery
 - periarterial lymphoid sheath (PALS)

Red Pulp

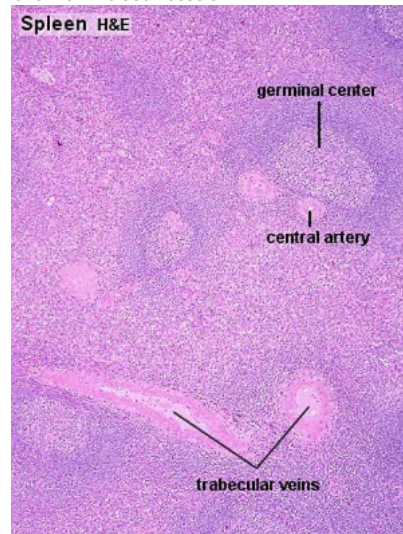
- splenic cords
 - macrophages
 - reticular fibroblasts
- splenic sinuses
 - endothelium (discontinuous structure)

Overview - red and white pulp



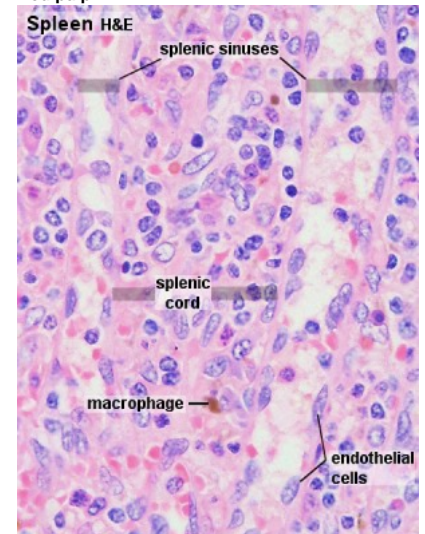
(/embryology/index.php/File:Spleen_histology_01.jpg)

Overview - blood vessels



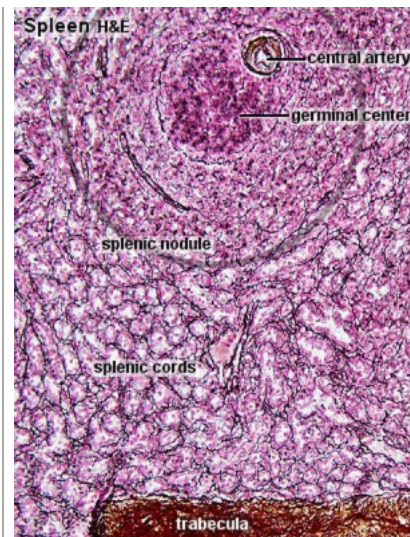
(/embryology/index.php/File:Spleen_histology_02.jpg)

Red pulp

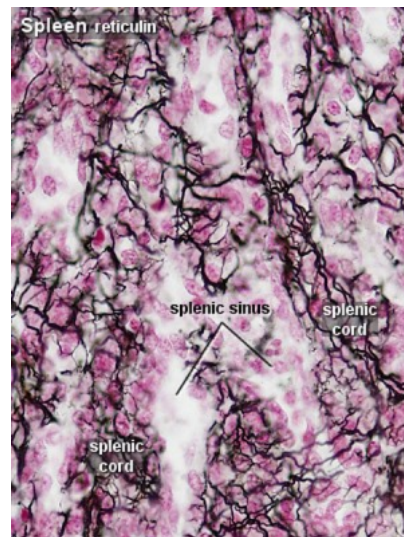


(/embryology/index.php/File:Spleen_histology_03.jpg)

Reticular Fibers (type III collagen) act as supporting meshwork (can be seen in Silver stained preparations)



(/embryology/index.php/File:Spleen_histology_05.jpg)



(/embryology/index.php/File:Spleen_histology_04.jpg)

Spleen Development (/embryology/index.php/Cardiovascular_System_-_Spleen_Development): SH Lecture Spleen (/embryology/index.php/SH_Lecture_-_Lymphatic_Structure_and_Organs#Spleen) | SH Adult Histology (/embryology/index.php/SH_Practical_-_Lymphatic_Structure_and_Organs#Spleen) | Overview Red and White Pulp (/embryology/index.php/File:Spleen_histology_01.jpg) | Overview Red and White Pulp (/embryology/index.php/File:Spleen_histology_02.jpg) | Cords and Sinuses (/embryology/index.php/File:Spleen_histology_03.jpg) | Reticular Fibre overview (/embryology/index.php/File:Spleen_histology_05.jpg) | Reticular Fibre detail (/embryology/index.php/File:Spleen_histology_04.jpg) | unlabeled red and white pulp (/embryology/index.php/File:Spleen_histology_06.jpg) | unlabeled red pulp and macrophages (/embryology/index.php/File:Spleen_histology_07.jpg) | unlabeled white pulp germinal centre (/embryology/index.php/File:Spleen_histology_08.jpg) | unlabeled reticular fibre (/embryology/index.php/File:Spleen_histology_09.jpg) | unlabeled white pulp reticular (/embryology/index.php/File:Spleen_histology_10.jpg) | unlabeled red pulp reticular (/embryology/index.php/File:Spleen_histology_11.jpg) | Structure cartoon (/embryology/index.php/File:Spleen_structure_02.jpg) | Cartoon and stain (/embryology/index.php/File:Spleen_structure_01.jpg) | Category:Spleen (/embryology/index.php/Category:Spleen) | Histology Stains (/embryology/index.php/Histology_Stains) | Immune System Development (/embryology/index.php/Immune_System_Development)

Additional Information

Additional Information - Content shown under this heading is not part of the material covered in this class. It is provided for those students who would like to know about some concepts or current research in topics related to the current class page.

Janeway's Immunobiology



(/embryology/index.php/File:Mark_Hill.jpg)

A useful resource textbook for further reading on **Lymphatic Structure and Organs** is Immunobiology (<http://www.ncbi.nlm.nih.gov/books/NBK10757/>) 5th edition The Immune System in Health and Disease Charles A Janeway, Jr, Paul Travers, Mark Walport and Mark J Shlomchik. Open links in a new tab if you wish to refer back to this lecture page.

I have included some links in this table below to specific notes and there is also available a complete list of contents (/embryology/index.php/Talk:SH_Lecture_-_Lymphatic_Structure_and_Organs#Immunobiology_3).

External Links Notice - The dynamic nature of the internet may mean that some of these listed links may no longer function. If the link no longer works search the web with the link text or name. Links to any external commercial sites are provided for **information purposes only** and should never be considered an endorsement. UNSW Embryology (/embryology/index.php/Main_Page) is provided as an educational resource (/embryology/index.php/Embryology:General_disclaimer) with no clinical information or commercial affiliation.

Immunobiology (<http://www.ncbi.nlm.nih.gov/books/NBK10757/>) 5th edition The Immune System in Health and Disease Charles A Janeway, Jr, Paul Travers, Mark Walport, and Mark J Shlomchik.

Part I. An Introduction to Immunobiology and Innate Immunity Chapter 1. Basic Concepts in Immunology

- The components of the immune system (<http://www.ncbi.nlm.nih.gov/books/NBK27092/>)
 - Figure 1.3 All the cellular elements of blood, including the lymphocytes of the adaptive immune system, arise from hematopoietic stem cells in the bone marrow (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A40>)
 - Figure 1.4 Myeloid cells in innate and adaptive immunity (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A41>)
 - Figure 1.5 Lymphocytes are mostly small and inactive cells (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A42>)
 - Figure 1.6 Natural killer (NK) cells (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A43>)
 - Figure 1.7 The distribution of lymphoid tissues in the body (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A45>)
 - Figure 1.8 Organization of a lymph node (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A47>)
 - Figure 1.9 Organization of the lymphoid tissues of the spleen (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A48>)
 - Figure 1.10 Organization of typical gut-associated lymphoid tissue (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A49>)
 - Figure 1.11 Circulating lymphocytes encounter antigen in peripheral lymphoid organs (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A51>)
- Summary to Chapter 1 (<http://www.ncbi.nlm.nih.gov/books/NBK27092/#A52>)

Part III. The Development of Mature Lymphocyte Receptor Repertoires Chapter 7. The Development and Survival of Lymphocytes

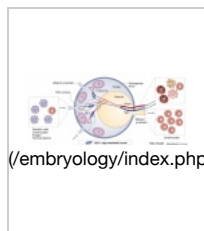
- Generation of lymphocytes in bone marrow and thymus (<http://www.ncbi.nlm.nih.gov/books/NBK27123/>)
 - Figure 7.3 The early stages of B-cell development are dependent on bone marrow stromal cells (<http://www.ncbi.nlm.nih.gov/books/NBK27123/figure/A803>)
 - Figure 7.5 The development of a B-lineage cell proceeds through several stages marked by the rearrangement and expression of the immunoglobulin genes (<http://www.ncbi.nlm.nih.gov/books/NBK27123/figure/A806>)
 - Figure 7.7 The cellular organization of the human thymus (<http://www.ncbi.nlm.nih.gov/books/NBK27123/figure/A809>)
 - Figure 7.13 Thymocytes at different developmental stages are found in distinct parts of the thymus (<http://www.ncbi.nlm.nih.gov/books/NBK27123/figure/A818>)
- Survival and maturation of lymphocytes in peripheral lymphoid tissues (<http://www.ncbi.nlm.nih.gov/books/NBK27150/>)

- Summary to Chapter 7 (<http://www.ncbi.nlm.nih.gov/books/NBK27123/#A819>)

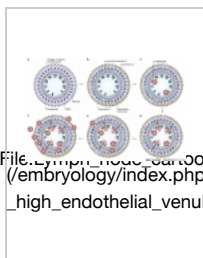


SH Practical - Lymphatic Structure and Organs (/embryology/index.php/SH_Practical_-_Lymphatic_Structure_and_Organs) associated practical support page. Note that virtual slides will be used in the associated practical class and this linked page provided for student self-directed learning of concepts from the virtual slides.

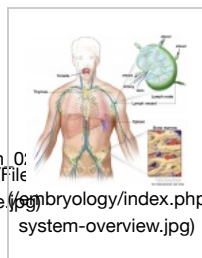
Lymphatic cartoon links (/embryology/index.php/File:Lymphatic-system-overview.jpg): Overview (/embryology/index.php/File:Lymphatic-system-overview.jpg) | Tonsil (/embryology/index.php/File:Lymphatic-system-tonsil.jpg) | Tonsil and MALT (/embryology/index.php/File:Lymphatic-system-tonsil-MALT.jpg) | Thymus (/embryology/index.php/File:Lymphatic-system-thymus.jpg) | Spleen (/embryology/index.php/File:Lymphatic-system-spleen.jpg) | Bone marrow (/embryology/index.php/File:Lymphatic-system-bone-marrow.jpg) | Lecture - Lymphatics | Immune System Development (/embryology/index.php/Immune_System_Development)



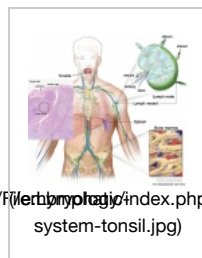
Cell Trafficking into and out of Lymph Nodes



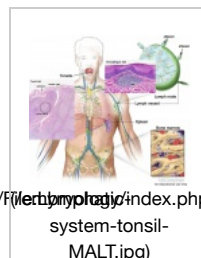
Lymphocyte Migration at High Endothelial Venule Model



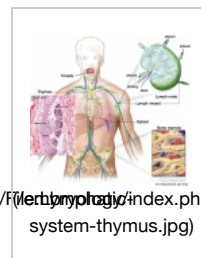
Overview



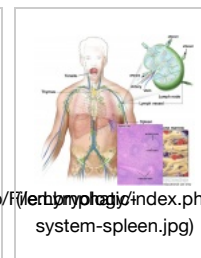
Tonsil



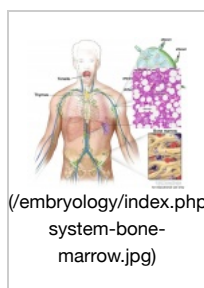
Tonsil and MALT



Thymus



Spleen



Bone marrow

Lymph Node Subcapsular Space Functions? [Expand]

Mouse Lymphocyte Motility Movies [Expand]

Additional Images [Expand]

- Figure - Gut associated lymphoid tissue (GALT) and systemic mucosal immunity (<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3144400/figure/F1/>)

Nature Immunology - Videos

Nature Immunology - These are short (5-10 min) animations showing how the immune system monitors the epithelial and environment interface at different anatomical locations:

Immunology in the skin



Immunology of the Lung



Immunology in the Gut Mucosa



YouTube Links

- Immunology of the skin (https://youtu.be/_VhcZTGv0CU)
- Immunology of the lung (https://youtu.be/rgphaHmAC_A)
- Immunology in the gut mucosa (https://youtu.be/gnZEge78_78)

Government Sources

These information pages provide general information to the public. See how the biology concepts have been simplified to make them more understandable.

USA

- Basic AIDS and Immune System Information (<https://www.aids.gov/hiv-aids-basics/just-diagnosed-with-hiv-aids/hiv-in-your-body/immune-system-101>)
- NIAD - Immune System (<http://www.niaid.nih.gov/topics/immunesystem/Pages/default.aspx>)

Australia

- Healthdirect HIV/AIDS (<http://www.healthdirect.gov.au/hiv-infection-and-aids>)

Blood Cells [Expand]

Anatomy of the Human Body (1918) - Lymphatics [Expand]

Textbook Links: MBoC Figure 24-6. The development and activation of T and B cells | [<http://www.ncbi.nlm.nih.gov/books/NBK26921/figure/A4430/> Figure 24-7. Electron micrographs of nonactivated and activated lymphocytes (<http://www.ncbi.nlm.nih.gov/books/NBK26921/figure/A4429/>) | Immunobiology - Figure 1.9. Organization of the lymphoid tissues of the spleen (<http://www.ncbi.nlm.nih.gov/books/NBK27092/figure/A48>)

Terms

A few key terms associated with the lymphoid system.

Immune Development (/embryology/index.php/Immune_System_Development)

- **adenoid** - (Greek " +*-oides* = in form of) in the form of a gland, glandular; the pharyngeal tonsil.
- **afferent lymph** - vessel carrying lymph towards a node.
- **acquired immune deficiency syndrome** - (AIDS) note this is now better described as "advanced HIV disease", decrease in the number of CD4 T cells. (More? Immunobiology AIDS (<https://www.ncbi.nlm.nih.gov/books/NBK27126/>))
- **anastomose** - joining of two tubes or structures together.
- **Antibody mediated immunity** - the immune function of plasma cells (active B lymphocytes) secreting antibody which binds antigen.
- **antibodies** - mammals have five classes (IgA, IgD, IgE, IgG, and IgM)
- **antigen** - any substance that is recognised by the immune system and stimulates antibody production.
- **appendix** - is a gut-associated lymphoid tissue (GALT) located at the beginning of the colon. The anatomy is as a finger-like structure that arises from the cecum. The length (13 cm) is longer in both infants and children and also has more abundant lymphatic tissue in early life. The wall structure is similar to the small intestine (though with no villi), plicae circularis. Lymph nodules surround the lumen of the gastrointestinal tract and extend from the mucosa into the submucosa.
- **B cell** - (B-cell, B lymphocyte) historically named after a structure called the **bursa** of Fabricius in birds, a source of antibody-producing lymphocytes. These immune cells develop in the bone marrow. (More? Electron micrographs of nonactivated and activated lymphocytes (/embryology/index.php/SH_Practical_-_Lymphatic_Structure_and_Organs#Lymphocyte_Electron_Micrographs))
- **blood** - see Cardiovascular terms (/embryology/index.php/Template:Cardiovascular_terms)
- **B lymphocyte** - (B cell, B-cell)
- **BALT** - (Bronchus Associated Lymphoid Tissue) immune tissue associated with the respiratory tract.
- **band cell** - (band neutrophil or stab cell) seen in bone marrow smear, a cell undergoing granulopoiesis, derived from a metamyelocyte, and leading to a mature granulocyte. occasionally seen in circulating blood.
- **caecum** - (caecum, Latin, *caecus* = "blind") within the gastrointestinal tract a pouch that connects the ileum with the ascending colon of the large intestine.
- **cell** - has a specific cell biology definition, but is often used instead of "lymphocyte" when describing B and T cells.
- **cell-mediated immunity** - the immune function of T lymphocytes. (More? Immunobiology - T Cell-Mediated Immunity (<https://www.ncbi.nlm.nih.gov/books/NBK10762/>))
- **central tolerance** - in thymus (/embryology/index.php/Thymus_Development) mediated by cortical epithelial cells, medullary epithelial cells and thymic dendritic cells, involving deletion of self-reactive thymocytes (T cell) (see [<https://www.ncbi.nlm.nih.gov/pubmed/30476234>] (<https://www.ncbi.nlm.nih.gov/pubmed/30476234>) PMID30476234).
- **"clockface"** - a term used to describe the appearance of plasma cell nuclei due to the clumping of the chromatin at the nucleus periphery. More clearly seen in tissue plasma cells than the bone marrow smear, where they are sometimes confused with the basophilic erythroblasts. Image - plasma cell (/embryology/index.php/File:Plasma_cell_clockface_nucleus_01.jpg)
- **CD** - (cluster of differentiation) identifies immunological surface markers on cells. Positive (+) generally means that the substance is expressed/identified, while negative (-) means that it is missing/not identified.
- **CD4+** - (T helper cells) refers to T lymphocytes that express CD4 (<https://www.omim.org/entry/186940>) (cluster of differentiation 4, a glycoprotein of the immunoglobulin superfamily) on their surface, associated with helper/inducer function. These cells can be infected by human immunodeficiency virus (HIV).
- **CD4/CD8 ratio** - clinical measurement of different immune cell types (ratios between 1.5 to 2.5 are considered normal). Viral infections such as HIV, cytomegalovirus, Epstein-Barr virus, and influenza virus, associated with an inversion of the ratio.
- **CD8+** - (cytotoxic T cells) refers to T lymphocytes that express CD8 (<https://www.omim.org/entry/186910>) (glycoprotein of the immunoglobulin superfamily) on their surface, associated with cytotoxic/suppressor activity.
- **"clockface"** - a term used to describe the appearance of plasma cell nuclei due to the clumping of the chromatin at the nucleus periphery. More clearly seen in tissue plasma cells than the bone marrow smear, where they are sometimes confused with the basophilic erythroblasts.
- **cords of Billroth** - spleen cellular columns located in red pulp. surrounded by splenic sinusoids. Cords contain reticular cells, macrophages, lymphocytes, plasma cells and erythrocytes.
- **cortex** - outer layer, used in association with medulla (inner layer or core) a general description that can be applied to describing an organ with a layered structure.
- **cortical Thymic Epithelial Cell** - (cTEC, types I - IV) support and antigen-presenting cells located in the cortex regions of the thymus (/embryology/index.php/Thymus_Development) required for positive and negative selection of maturing T cells. See also medullary epithelial cell.
- **dendritic cell** - (DC, antigen-presenting cell, APC) cells that present antigens and induce a primary immune response in resting naïve T lymphocytes. Originate from the same common progenitor as monocytes (PMID 20193011). In 2011 Ralph M. Steinman received half the Nobel Prize (http://www.nobelprize.org/nobel_prizes/medicine/laureates/2011) half of the award to Ralph M. Steinman for his discovery of the dendritic cell and its role in adaptive immunity.
- **Effector cells** - the immune functioning (active) B and T lymphocytes.
- **Efferent lymph** - vessel carrying lymph away from a node.
- **fibroblastic reticular cell** - (FRC) specialized myofibroblasts that form the structural mesenchymal network "sponge" within lymphoid tissue that regulate immune cell migration, activation, and survival. Immune T cells, B cells, dendritic cells (DCs), plasma cells and macrophages move and interact.
- **follicular dendritic cell** - (FDC) in B cell follicles of secondary lymphoid organs, cells interspersed within the stromal cell network function: Primary - help B cells to cluster. Secondary - in GC long-term retention of intact antigen and support B cell survival.
- **GALT** - Gut Associated Lymphatic Tissue consisting of Peyer's patches, isolated lymphoid follicles and mesenteric lymph nodes.
- **germinal centre** - (GC) centre of B cell follicles of secondary lymphoid organs, where antigen-activated B-cell clones expand and undergo immunoglobulin gene hypermutation and selection.
- **haemopoiesis** (hemopoiesis) formation of blood cells.
- **Hassall's corpuscles** (/embryology/index.php/Thymus_Development#Hassall.E2.80.99s_Corpuscles) - (Hassall's body, thymic corpuscle) Epithelial reticular cells located in the thymic medulla. Named after Arthur Hill Hassall (/embryology/index.php/File:Arthur_Hill_Hassall.jpg) (1817-1894) a British physician and chemist.
- **high endothelial venule** - (HEV) the specialised post-capillary venous region that enables blood lymphocytes to enter a lymph node. These specialised post-capillary venules enable blood lymphocytes to enter a lymph node. The endothelial cells express ligands that bind lymphocytes, aiding their adhesion and subsequent transmigration into the lymph node (/embryology/index.php/Lymph_Node_Development).
- **humoral immune response** - production of antibody by plasma cells derived from B lymphocytes (B cells).
- **IEL** - Intraepithelial Lymphocyte are T lymphocytes located in the gastrointestinal tract epithelium. Natural IELs (previously 'type b' IELs) acquire activated phenotype during development in the thymus in the presence of self antigens. Induced IELs (previously 'type a' IELs) progeny of conventional T cells activated post-thymically in response to peripheral antigens.
- **IgA** - the main class of antibody in secretions (saliva, tears, milk, and respiratory and intestinal secretions).
- **IgD** - the immunoglobulin B cell starts to produce as a cell-surface molecule after leaving the bone marrow.
- **IgE** - bind Fc receptors (surface of mast cells in tissues and basophils in the blood) release of potent pro-inflammatory molecules mediators of allergic reactions.
- **IgG** - the major class of immunoglobulin in the blood.
- **IgM** - the first class of antibody made by a developing B cell, which may switch to making other classes of antibody.
- **immunodeficiency** - when one or more components of the immune system is defective. (More? Immunobiology - immunodeficiency (<http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Search&db=books&rid=imm.section.1494>))
- **immunoglobulin** - (antibody, Ab) protein produced by plasma cells.
- **immunosenescence** - in ageing and disease, refers to weaker immune responses producing a progressive deterioration and increased susceptibility to infectious disease.

neoplasia, and autoimmune diseases.

- **innate lymphoid cells** - (ILCs) subset of lymphocytes that lack antigen-specific receptors, are located in peripheral tissues and abundant at barrier surfaces, decrease in number with age. PMID 29924974 (<https://www.ncbi.nlm.nih.gov/pubmed/29924974>)
- **intraepithelial lymphocyte** (IEL) immune cells residing in the gastrointestinal tract epithelium. image - Intraepithelial lymphocyte differentiation (/embryology/index.php/File:Intraepithelial_lymphocyte_differentiation_01.jpg)
- **involution** - in the thymus refers to the replacement, mainly in the cortex, of cells by adipose tissue. (More? PubMed- thymus involution (<http://www.ncbi.nlm.nih.gov/entrez.fcgi?db=PubMed&cmd=Search&term=thymus+involution&doptcmdl=Books>) | Cancer Medicine - Thymomas and Thymic Tumors (<http://www.ncbi.nlm.nih.gov/entrez/quer.fcgi?db=PubMed&cmd=Search&term=thymoma+involution&doptcmdl=Books>))
- **Kupffer cells** - stellate macrophage cells located in the liver sinusoids, named after Karl Wilhelm von Kupffer (1829 - 1902) a German anatomist who originally identified these cells. (More? Liver Development (/embryology/index.php/Gastrointestinal_Tract_-_Liver_Development))
- **lacteal** - term used to describe the lymphatic vessels of the small intestine.
- **lamina propria** - a layer of loose connective tissue found underneath an epithelium, together with the epithelium described as mucosa.
- **Langerhans cell** - (LC, dendritic cell) Antigen-presenting immune cell found mainly in the basal/suprabasal layers of adult skin and mucosa. Cells lie in the basal/suprabasal layers of stratified epidermal and mucosal tissues. First in the innate antiviral immune defines and can migrate to lymph nodes and induce a T cell-mediated adaptive immune response. (More? Integumentary (/embryology/index.php/Integumentary_System_Development#Langerhans_Cells) | Immune System Development (/embryology/index.php/Immune_System_Development))
- **Leukocyte** - (Greek, *lukos* = clear, white) white blood cell.
- **lingual** - related to the tongue.
- **lymph node** - connective tissue encapsulated lymphoid organ (1mm - 2cm in size), positioned in the pathway of lymph vessels. (More? Lymph Node Development (/embryology/index.php/Lymph_Node_Development))
- **lymphangion** - the functional unit of a lymph vessel that lies between two semilunar (half moon-shaped) valves.
- **lymphangiogenesis** - formation of new lymph vessels from pre-existing lymphatic structures. During embryogenesis and in adult tissues as reaction to inflammation or injury.
- **M cell** - (microfold cell) found in the follicle-associated epithelium of the Peyer's patch. Function to transport gut lumen organisms and particles to immune cells across the epithelial barrier.
- **macrophage** - a large highly motile white blood cell which engulfs foreign material (bacteria etc) and both degenerating cells and cell fragments. Differentiates from a monocyte and found in many different tissues and locations. Current theory suggests tissue macrophage is also derived from resident stem cell population in many tissues. More? Immunobiology - Defects in phagocytic cells are associated with persistence of bacterial infection (<http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=imm.figgrp.1508>)
- **MALT** - Mucosa Associated Lymphoid Tissue.
- **medulla** - inner layer or core, used in association with cortex (outer layer) a general description that can be applied to describing an organ with a layered structure.
- **medullary Thymic Epithelial Cell** - (mTEC, types I-VII) support and antigen presenting cells located in the medullary regions of the thymus (/embryology/index.php/Thymus_Development), required for central tolerance (negative selection) of maturing T cells (PMID 11375064 (<https://www.ncbi.nlm.nih.gov/pubmed/11375064>)). See also cortical thymic epithelial cell.
- **Memory Cell** - effector T cell (lymphocyte)
- **mesenteric lymph nodes** - Part of GALT as well as being involved in gut-draining. image - mesenteric lymph nodes (/embryology/index.php/File:Gastrointestinal_tract_intestine_immune_cartoon_01.jpg)
- **Mononuclear Phagocytic System** - (MPS, Lymphoreticular System, Reticuloendothelial System, RES) Consists of circulating monocytes in the peripheral blood and non-circulating (fixed) tissue macrophages (MΦ) located in tissues and organs.
- **negative selection** - T cells bearing autoreactive T cell antigen receptors (TCRs) are eliminated during their development in the thymus, protects against autoimmunity.
- **normoblast** - seen in bone marrow smear, a developing erythroblast (red blood cell) that still retains a nucleus.
- **nude mice** - (nu/nu) mice which are congenitally hairless and athymic, therefore they do not reject tissue and tumor grafts.
- **parenchyma** - (Greek = *enkeim* "to pour in") cells forming the functional cells of an organ or tissue. These cells carry out the function of the organ at a cellular level, and are the structural cells, connective tissue, extracellular matrix (stromal).
- **periarterial lymphoid sheath** - (PALS) in the spleen the white pulp that surrounds the central arteries. (T-lymphocytes, macrophages and plasma cells)
- **pharyngeal pouch III** - origin of endodermal component of the thymus (also formed from neural crest). Pharyngeal arches (/embryology/index.php/Pharyngeal_arches)
- **Plasma Cell** - active B cell (lymphocyte) which is secreting antibody. Located in either bone marrow or peripheral lymphoid tissues, these cells have an increased cytoplasmic volume (due to increased rough endoplasmic reticulum) in comparison to the inactive (non-secreting) lymphocyte.
- **primary follicle** - follicle that does not contain germinal centre, secondary follicles do contain germinal centre.
- **red pulp** - spleen region, organized as cell cords (splenic cords, cords of Billroth) and vascular sinuses.
- **regulatory T cells** - (Tregs) maintain self tolerance and suppress pathological immune responses by control of immune response to non-self antigens.
- **right lymphatic duct** - drains most of the right upper quadrant. See also thoracic duct.
- **secondary follicle** - contain germinal centre, primary follicle does not contain germinal centre.
- **sentinel lymph node** - the hypothetical first lymph node or group of nodes reached by metastasizing cancer cells from a primary tumour.
- **splenic capillary sheaths** - in spleen (/embryology/index.php/Cardiovascular_System_-_Spleen_Development) around capillary endothelium and consist of three main cell types: CD271+ stromal capillary sheath cells, CD68+CD163+ macrophages and recirculating B-lymphocytes. Sheaths may; 1. allow interaction among sheath macrophages and B-lymphocytes, 2. attract recirculating B-lymphocytes from the open circulation of the red pulp to start migration into white pulp follicles. 30356180 (<https://www.ncbi.nlm.nih.gov/pubmed/30356180>)
- **splenic sinusoids** - enlarged splenic spaces located in red pulp and surrounding cords of Billroth.
- **stroma** - (Greek = "a cover, table-cloth, bedding") tissue forming the framework/support of an organ or tissue. That is the structural cells which form connective tissue and secrete extracellular matrix, rather than the functional cells (parenchymal). All organs can therefore be functionally divided into these 2 components, stromal/parenchymal.
- **Subcapsular sinus** (=marginal sinus) space lying under the connective tissue capsule which receives lymph from afferent lymphatic vessels.
- **T cell** - (T-cell, T lymphocyte) named after thymus, where they develop, the active cell is responsible for cell-mediated immunity (killer T cells and helper T cells). Cells express cell receptor on surface and directly kill virally or bacterially infected cells. These cells can themselves be infected by HIV. (More? Electron micrographs of nonactivated and activated lymphocytes (/embryology/index.php/SH_Practical_-_Lymphatic_Structure_and_Organs#Lymphocyte_Electron_Micrographs))
- **TEC** - (Thymic Epithelial Cell) thymus (/embryology/index.php/Thymus_Development) support and antigen presenting cells further divided anatomically and functionally into medullary TEC (mTEC, types I-VII, for central tolerance) and cortical epithelial cell (cTEC, types I-IV, positive and negative selection) populations (see PMID 28800929 (<https://www.ncbi.nlm.nih.gov/pubmed/28800929>) PMID 30308217 (<https://www.ncbi.nlm.nih.gov/pubmed/30308217>)).
- **T cell activation** - (T lymphocyte activation) The activation process begins with T-cells searching for and encountering antigen-bearing dendritic cells within lymph nodes.
- **thoracic duct** - largest lymphatic vessel, drains the lower body including the extremities and abdomen.
- **Thymic corpuscle** - (Hassall's corpuscle) a mass of concentric epithelioreticular cells found in the thymus. The number present and size tend to increase with thymus age. (classical description of Hammar, J. A. 1903 Zur Histogenese und Involution der Thymusdrüse. Anat. Anz., 27: 1909 Fünfzig Jahre Thymusforschung. Ergebn. Anat. Entwickl.-Gesch. 19: 1-274.)
- **thymic epitheliocytes** - reticular cells located in the thymus cortex that ensheath the cortical capillaries, creating and maintain the microenvironment necessary for the development of T-lymphocytes in the cortex.

- **T helper cells** - (helper T-cells) (T_H cells, CD4+) refers to T lymphocytes that when mature express CD4 (glycoprotein of the immunoglobulin superfamily) on their surface.
- **T lymphocyte** - (T cell, T-cell) regulate cell-mediated immunity.
- **thymus** - an immune/endocrine (thymic hormone) organ involved in the maturation of T lymphocytes (T-cells). Thymus Development (/embryology/index.php/Thymus_Development)
- **tonsils** - lymph nodules embedded in the mucus membranes located at the back of the mouth and top of the throat. The overlying epithelium helps identify the location.
- **vermiform appendix** - see appendix, anatomical region containing gut-associated lymphoid tissue located within the gastrointestinal tract at the beginning of the colon. The anatomy is as a finger-like structure that arises from the cecum. The length (2.5-13 cm) is longer in both infants and children and also has more abundant lymphatic tissue in life. The wall structure is similar to the small intestine (though with no villi), nor plicae circularis. Lymph nodules surround the lumen of the gastrointestinal tract and extend from the mucosa into the submucosa.
- **VDJ recombination** - (variable, diversity and joining gene segments) genetic recombination event that occurs in immune cell maturation in primary lymphoid organs, B cells ((bone marrow) and T cells (thymus).
- **Waldeyer's ring** - ring of lymphoid tissue in the pharyngeal wall: palatine tonsils, nasopharyngeal tonsil (adenoid) and lingual tonsil. First described in 1884 by von Waldeyer.
- **white pulp** - (Malpighian bodies of the spleen (/embryology/index.php/Embryology_Historic_Terminology), splenic lymphoid nodules) spleen lymphoid region, organized as lymphoid sheaths with both T-cell and B-cell compartments, around the branching arterial vessels (resembles lymph node structure).

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