

Tissues of the Immune System

Anatomical organization of adaptive immunity

Primary organs
Lymphocyte development



Secondary organs
Antigen-driven responses

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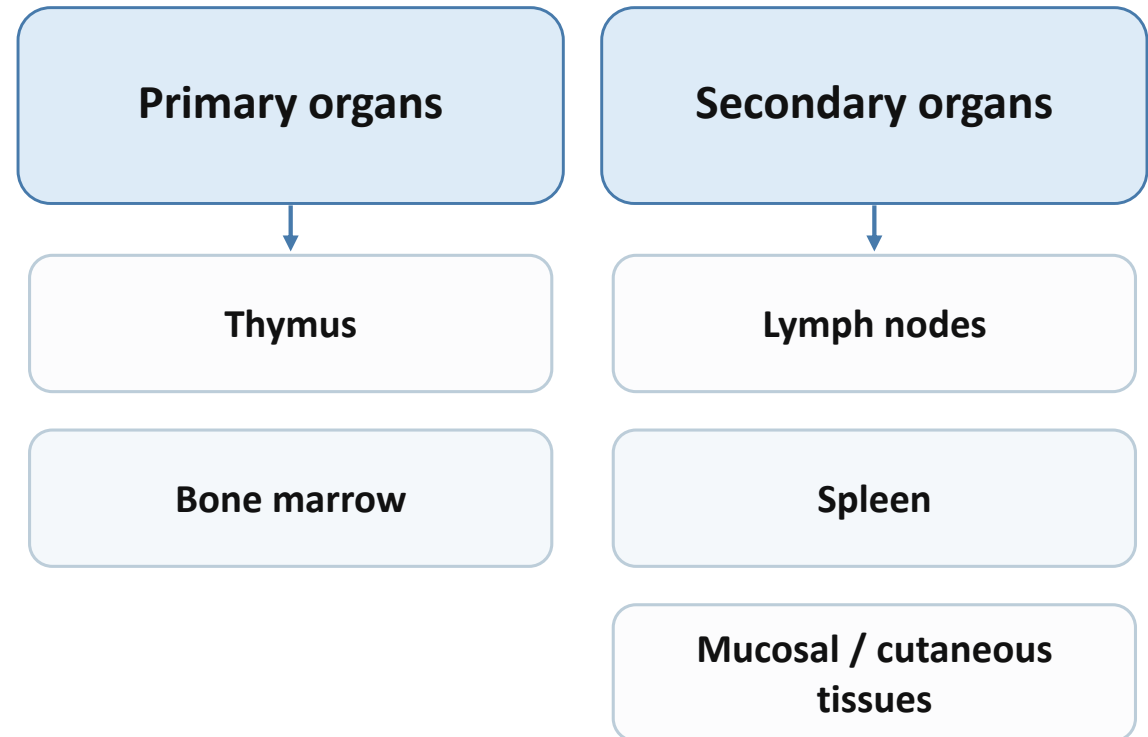
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Learning objectives

- Distinguish primary from secondary lymphoid organs by developmental and immune functions.
- Trace antigen delivery to lymph nodes, spleen and barrier-associated lymphoid tissues.
- Identify T-cell and B-cell compartments in lymph nodes and splenic white pulp.
- Explain how dendritic cells, follicular dendritic cells and macrophages support immunity.
- Contrast trafficking of naive lymphocytes, effector T cells and antibody-secreting plasma cells.

Immune tissues are organized by function

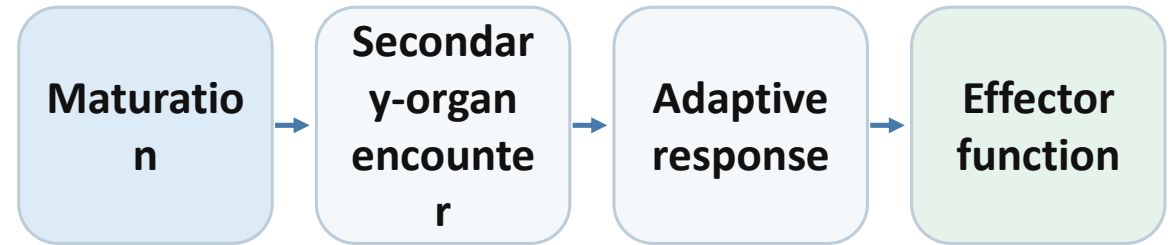
- Primary (central) organs generate immunocompetent lymphocytes.
- Secondary (peripheral) organs initiate adaptive responses to microbes.
- Anatomical specialization links maturation, antigen capture and effector action.



Organ classification · schematic

Primary and secondary organs form a functional network

- Lymphocytes develop in generative sites before entering peripheral immune surveillance.
- Antigen is concentrated at secondary sites where circulating lymphocytes search.
- Activated effectors subsequently function beyond the site of initiation.



Functional sequence · schematic

Primary organs prepare cells for antigen recognition

- Their defining task is lymphocyte development and acquisition of responsiveness.
- T- and B-cell maturation occurs at anatomically distinct sites.
- This stage is different from initiation of a response to a peripheral microbe.

Generative

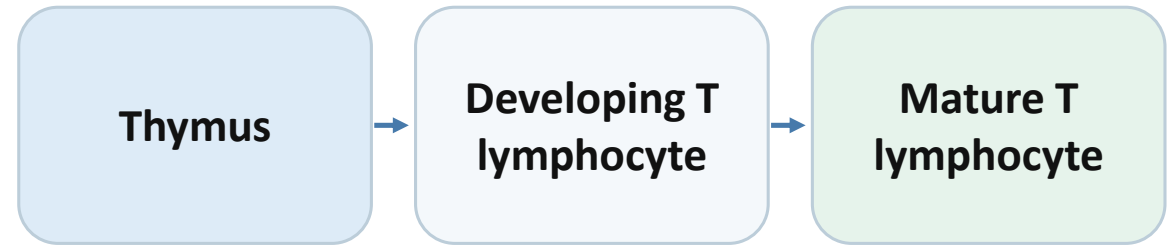
Cells mature and
become competent

Peripheral

Antigen-driven
responses begin

The thymus is the site of T-cell development

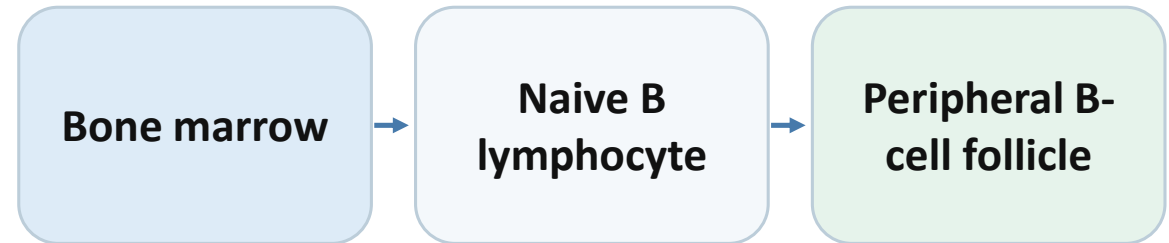
- The thymus is a primary lymphoid organ.
- T lymphocytes mature here before participating in peripheral adaptive responses.
- This developmental role distinguishes thymus from lymph-node T-cell zones.



Functional sequence · schematic

Bone marrow is a central lymphocyte-generative site

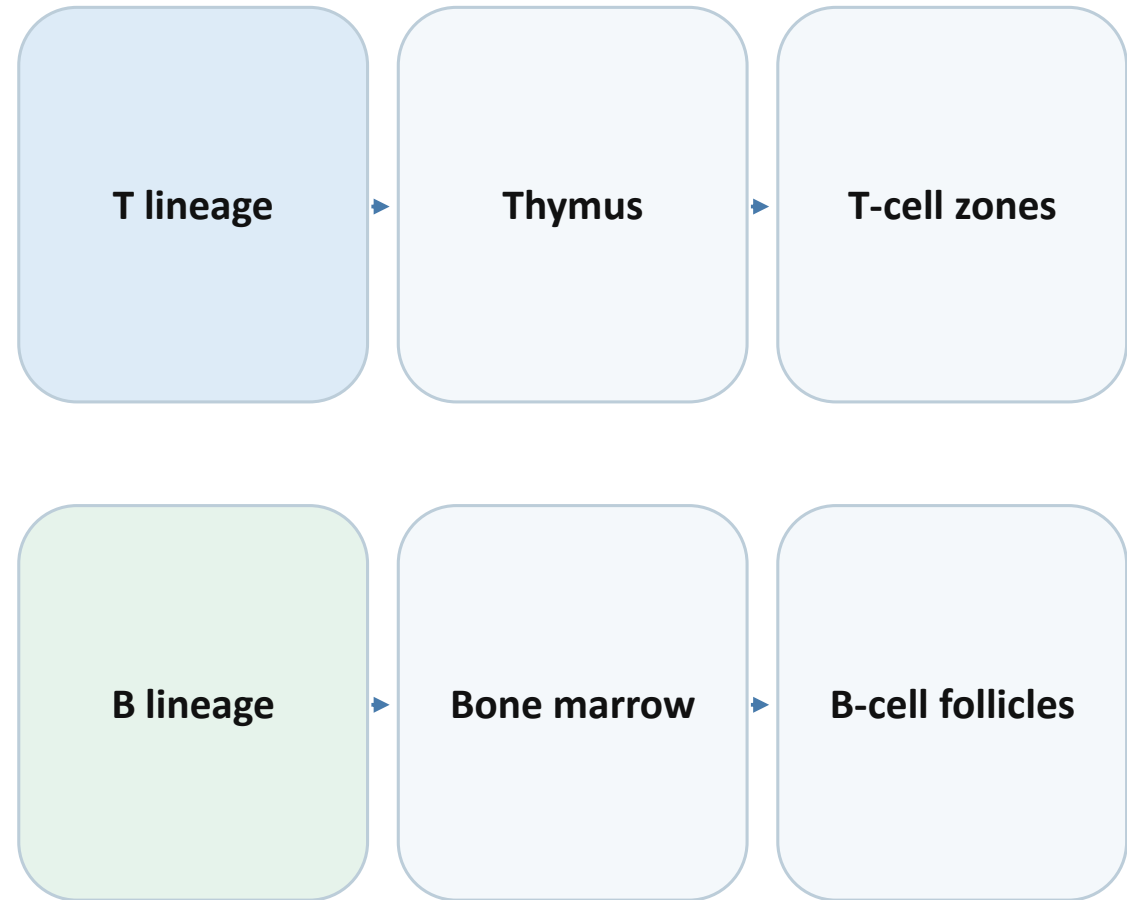
- Bone marrow produces blood cells, including naive B lymphocytes.
- It is the primary organ emphasized for B-cell generation.
- Later, plasma cells may reside in marrow while secreting antibodies.



Functional sequence · schematic

T- and B-cell developmental sites differ

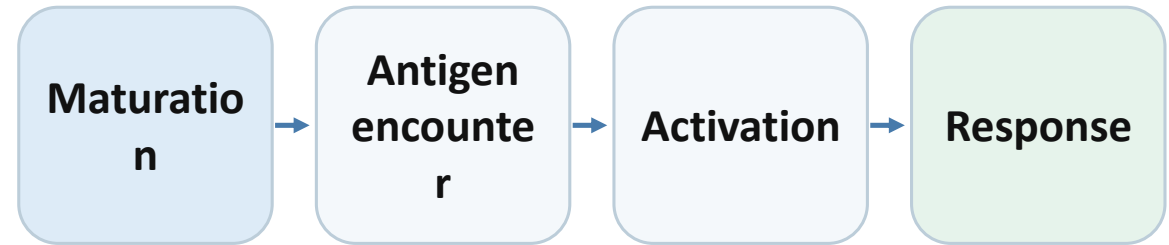
- T lineage: Thymic development is the central-organ role.
- B lineage: Bone marrow generates naïve B cells.
- Both lineages subsequently participate in peripheral adaptive immunity.



Parallel pathways · schematic

Maturation and activation are distinct events

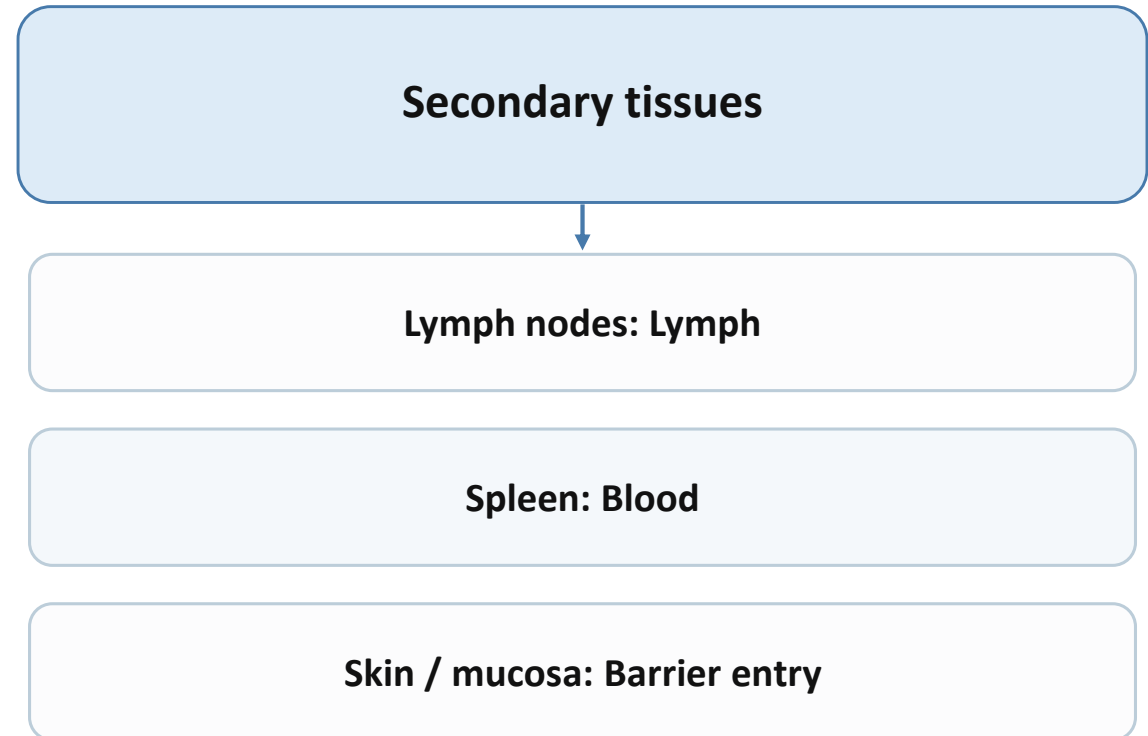
- Maturation yields lymphocytes capable of responding to antigen.
- Initiation occurs when antigen is presented or encountered in secondary organs.
- Effector-cell migration is a subsequent, functionally separate phase.



Functional sequence · schematic

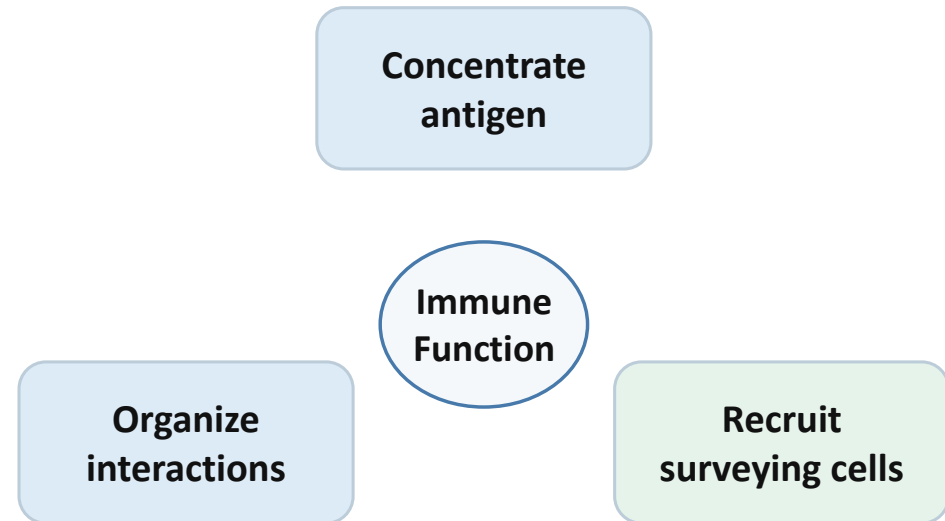
Secondary organs are sites of adaptive immune initiation

- Major sites are lymph nodes, spleen and lymphoid tissues associated with barriers.
- Their architecture concentrates antigens and circulating naive lymphocytes.
- Spatial organization helps coordinate cellular and humoral arms.



Three architectural advantages promote immunity

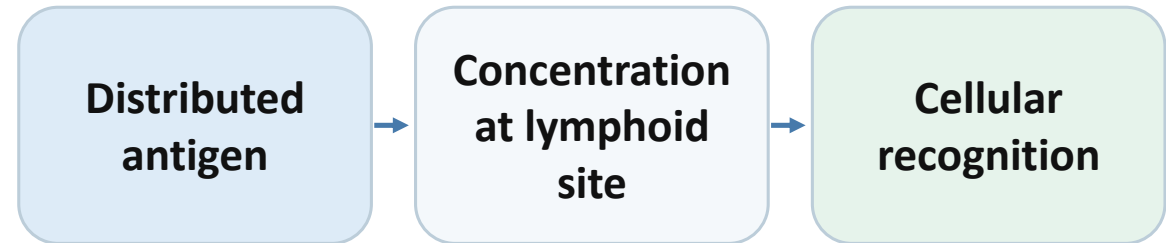
- Antigens are delivered to, trapped in or carried into these organs.
- Naive lymphocytes circulate through the same sites searching for antigen.
- T and B cells occupy organized neighborhoods that enable coordination.



Conceptual relationship · schematic

Antigen capture increases local encounter opportunity

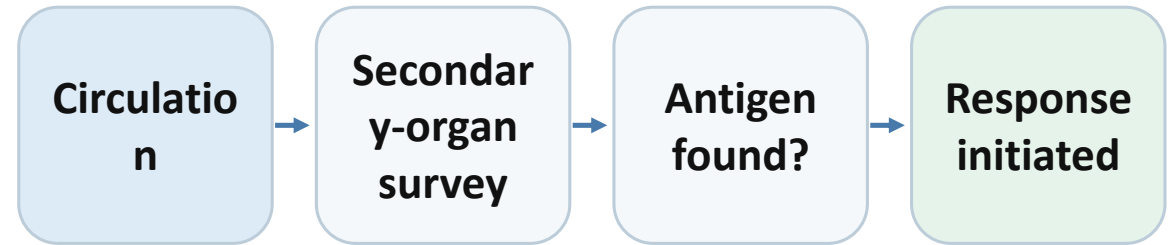
- Without concentration, antigen and rare responsive lymphocytes may remain separated.
- Secondary-organ filtering brings antigens and adaptive immune cells together.
- The delivery route determines whether a node, spleen or barrier tissue is engaged.



Functional sequence · schematic

Naive lymphocytes survey secondary lymphoid tissue

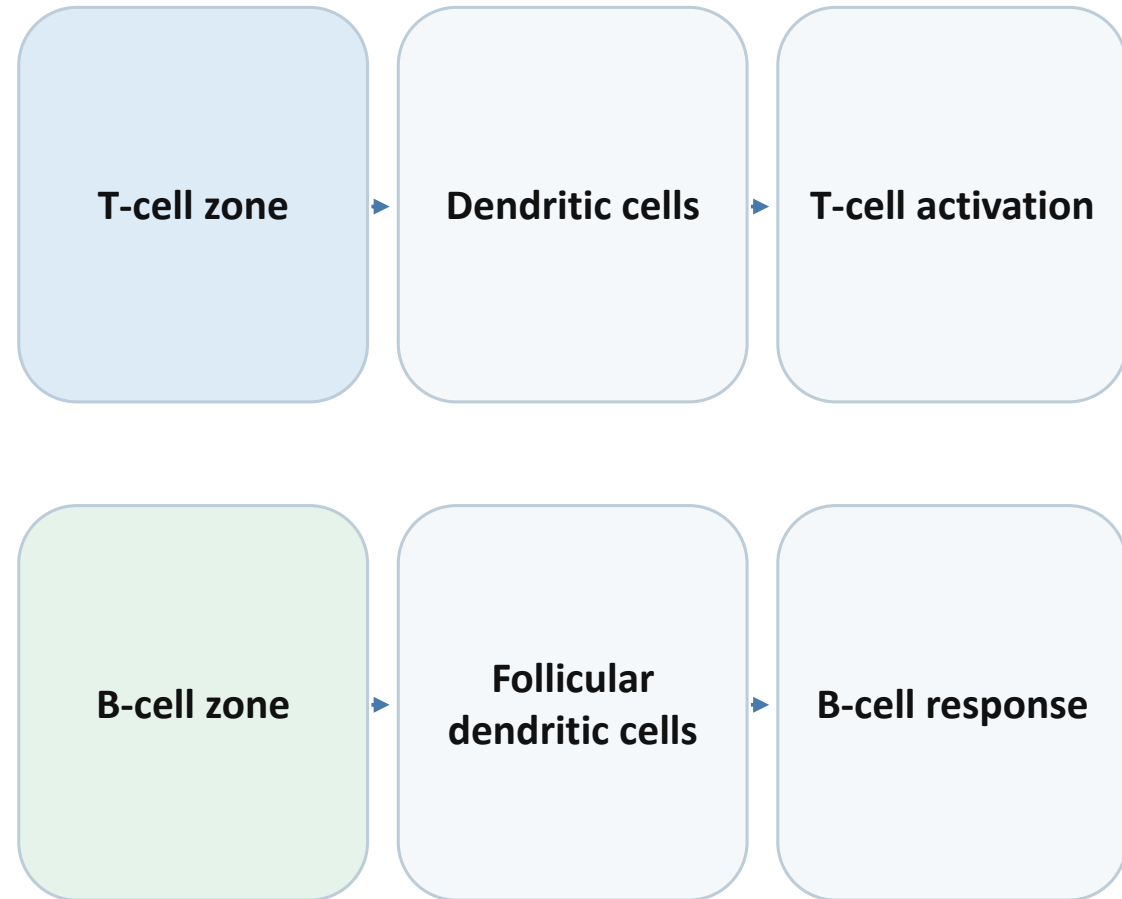
- Naive lymphocytes travel between blood and peripheral lymphoid organs.
- Their repeated passage allows searching where microbial antigens accumulate.
- This trafficking is particularly important for naive T cells.



Functional sequence · schematic

T- and B-cell zoning partitions immune work

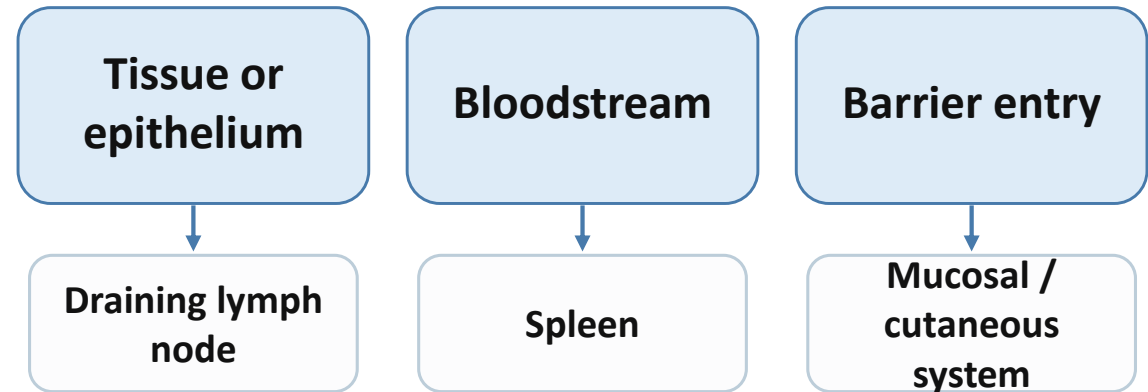
- T lymphocytes localize preferentially to dedicated T-cell compartments.
- B lymphocytes concentrate in follicular areas.
- Different antigen-presenting cells are associated with these neighborhoods.



Parallel pathways · schematic

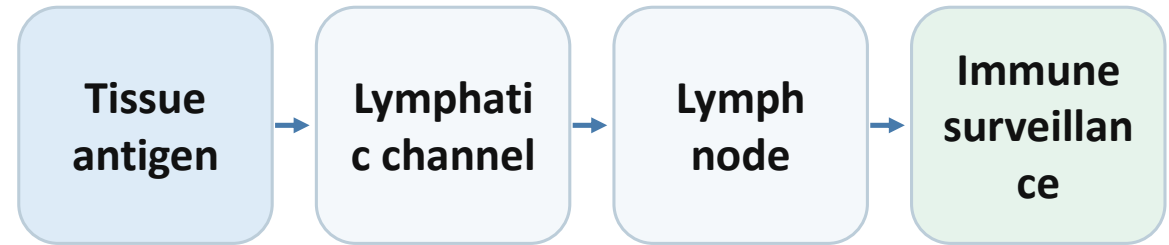
Antigen entry route predicts the responding organ

- Tissue or epithelial antigens may move in lymph to draining lymph nodes.
- Blood-borne antigens are monitored by the spleen.
- Barrier-associated lymphoid tissue responds at mucosal and cutaneous surfaces.



Lymph nodes sample antigens from tissue drainage

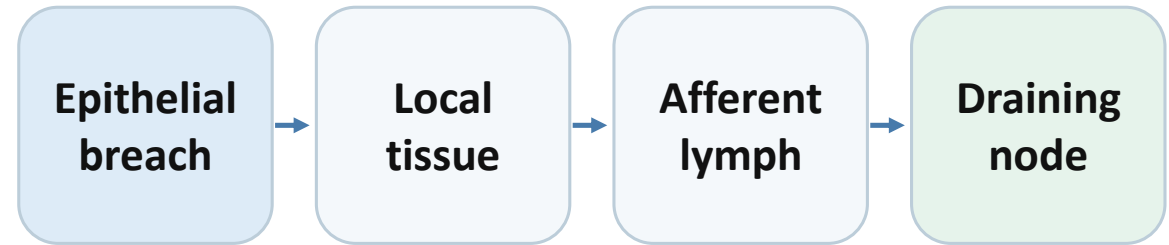
- Nodes are nodular aggregates located along lymphatic channels.
- Lymph flows slowly through nodes, allowing antigen surveillance.
- APCs in nodes can recognize antigen brought from peripheral tissues.



Functional sequence · schematic

Their position along lymphatics is functional

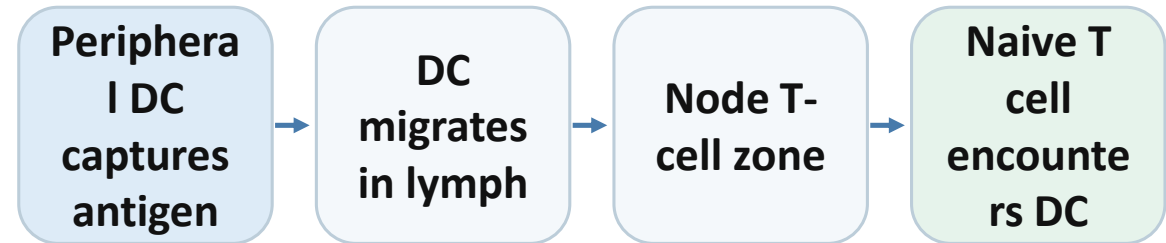
- Foreign material reaching tissue spaces can enter lymphatic drainage.
- A node intercepts the lymph traversing that drainage territory.
- This arrangement explains why the draining node receives localized tissue antigens.



Functional sequence · schematic

Dendritic cells transport sampled antigens to nodes

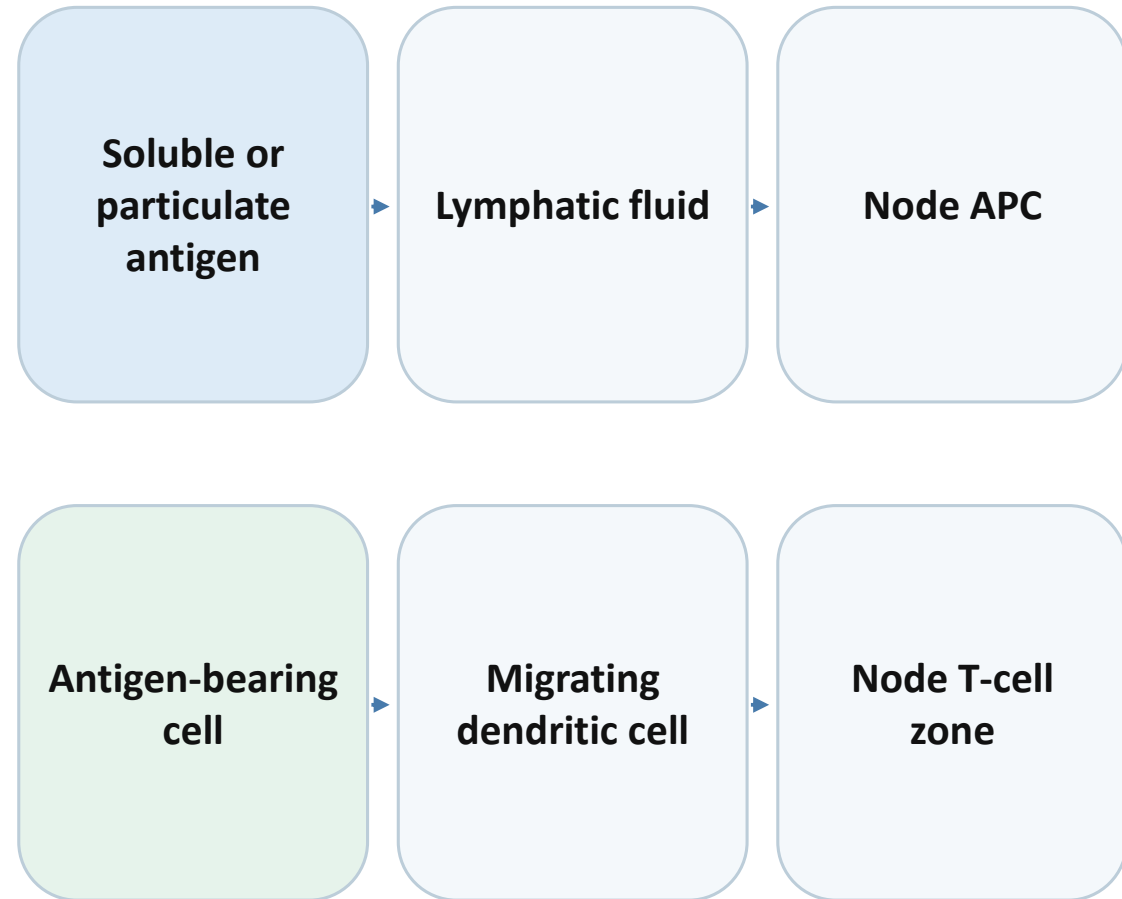
- Dendritic cells are located below epithelia and in tissue interstitium.
- They capture microbial material and travel by lymphatics to lymph nodes.
- They enter T-cell zones where naive T cells can recognize presented peptides.



Functional sequence · schematic

Antigens can also arrive directly in lymph

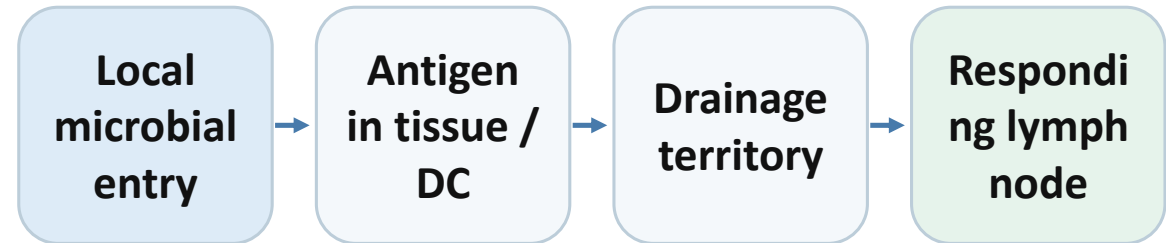
- Microbial antigens entering tissues may be transported in lymph.
- APCs within nodes are positioned to recognize these incoming materials.
- This complements transport by antigen-bearing dendritic cells.



Parallel pathways · schematic

A draining lymph node concentrates tissue antigen

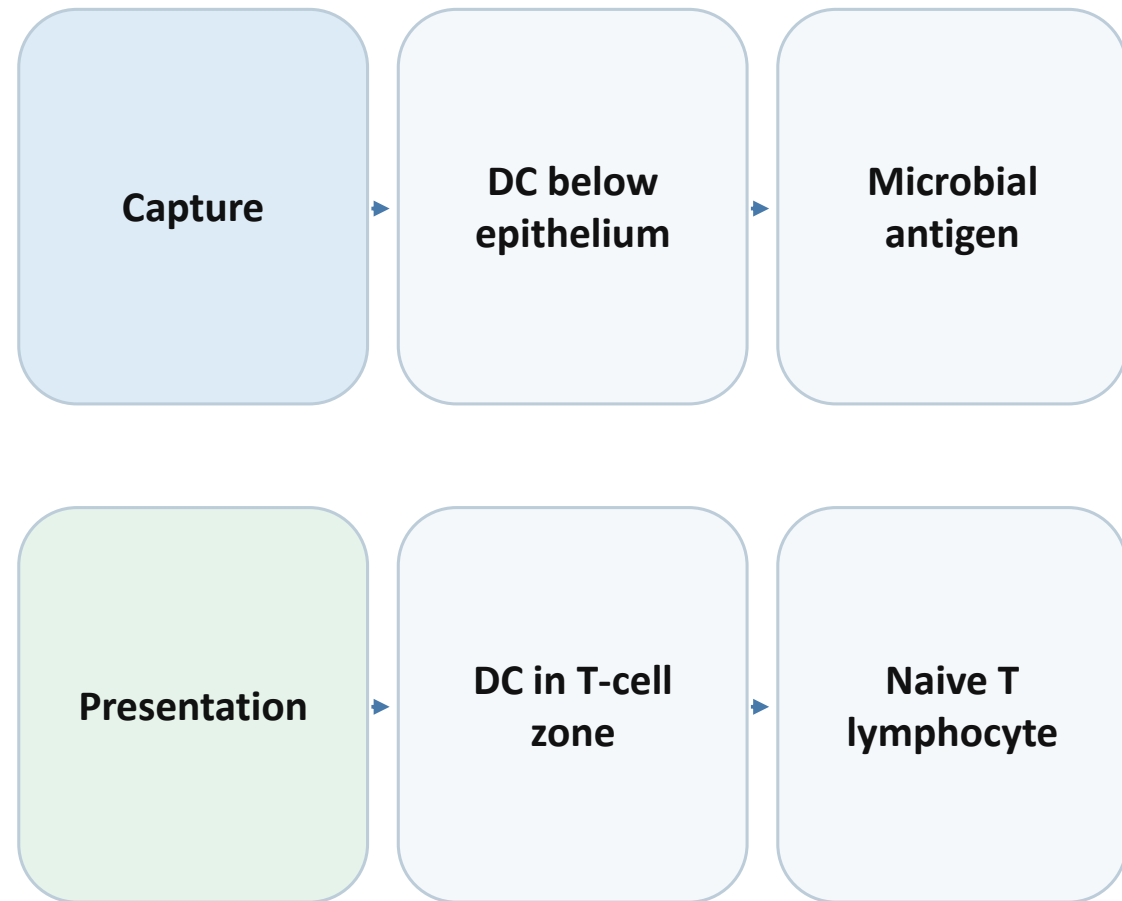
- Antigens from microbes entering epithelia or local tissues converge via drainage.
- Lymphatic delivery makes antigen available within the node.
- Because many foreign antigens enter through tissues, nodes initiate many responses.



Functional sequence · schematic

Conventional dendritic cells initiate T-cell responses

- Dendritic cells are major antigen-presenting cells for naive T cells.
- They express high levels of MHC and molecules needed for T-cell activation.
- Their location in T-cell zones aligns the APC with its principal target.



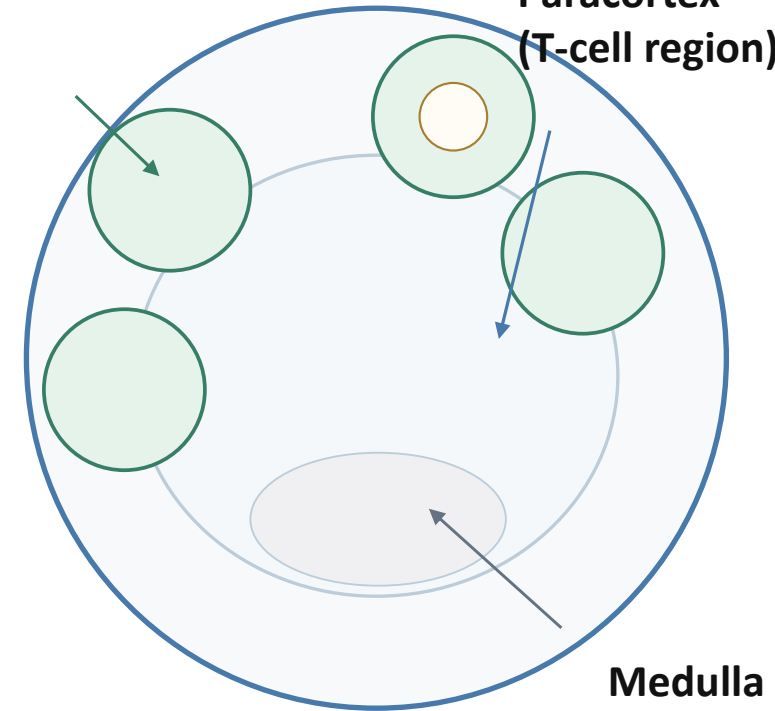
Parallel pathways · schematic

The lymph-node cortex contains B-cell follicles

- Follicles lie around the peripheral cortex of a lymph node.
- They are sites of concentrated B lymphocytes.
- Follicular dendritic cells support antigen recognition within follicles.

**Cortical B-cell
Follicles**

**Paracortex
(T-cell region)**



Simplified lymph-node compartment schematic—not an H&E section

Follicles are organized B-cell compartments

- The follicle is an anatomical lymphocyte neighborhood rather than a random cluster.
- B cells localize near FDCs that retain antibody- or complement-bound antigen.
- Such proximity supports development of humoral immune responses.

B cell

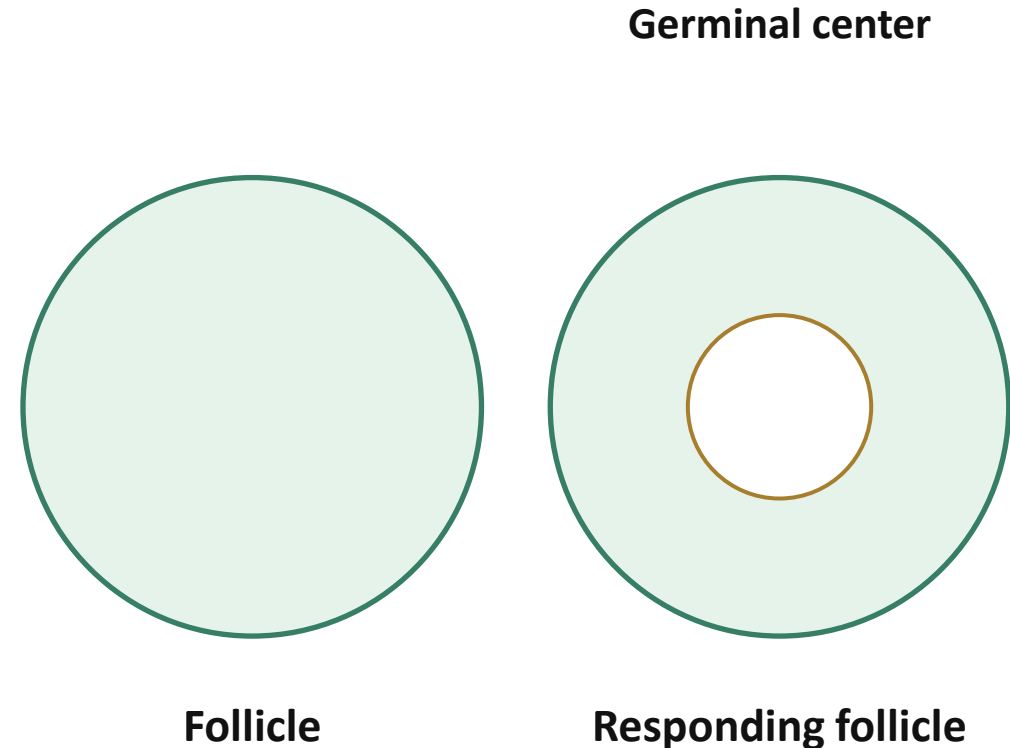
Recognizes antigen
within follicular milieu

FDC

Traps antigen
complexes for B cells

Recent B-cell activation can produce germinal centers

- A follicle that has recently responded to antigen may develop a germinal center.
- The germinal center occupies the central part of that responding follicle.
- Its presence indicates an antigen-responsive follicular compartment in this source.



Antigen response may produce a central germinal center

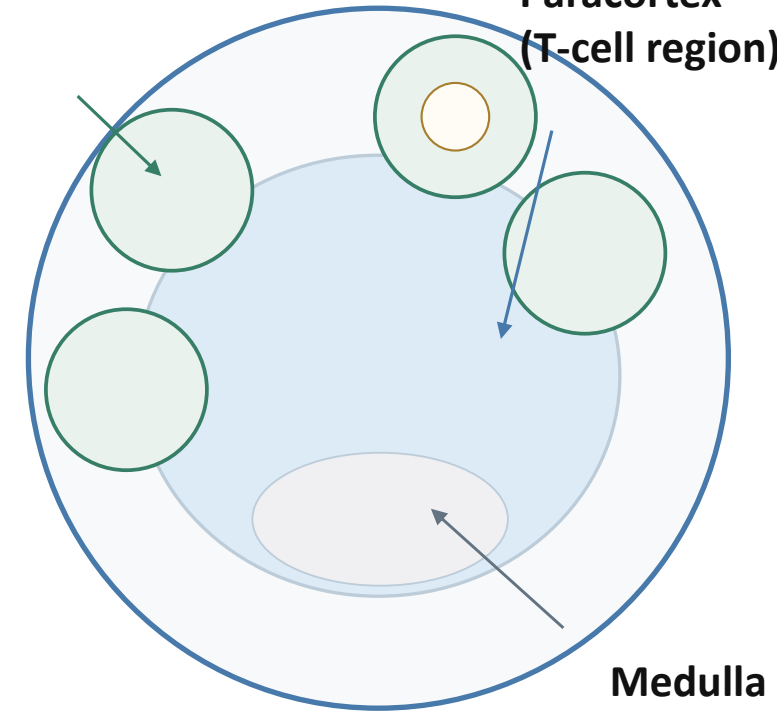
Simplified follicular schematic; Not a histology image

The paracortex contains concentrated T lymphocytes

- The T-cell-rich paracortex lies next to the cortical follicles.
- Conventional dendritic cells reside in this compartment.
- The arrangement enables antigen presentation to T lymphocytes.

**Cortical B-cell
Follicles**

**Paracortex
(T-cell region)**



Simplified lymph-node compartment schematic—not an H&E section

Antigen-presenting cells are compartment-specific

- Conventional dendritic cells present antigen to T cells in the paracortex.
- Follicular dendritic cells display trapped antigen to B cells in follicles.
- The two dendritic populations differ in lineage and immunologic function.

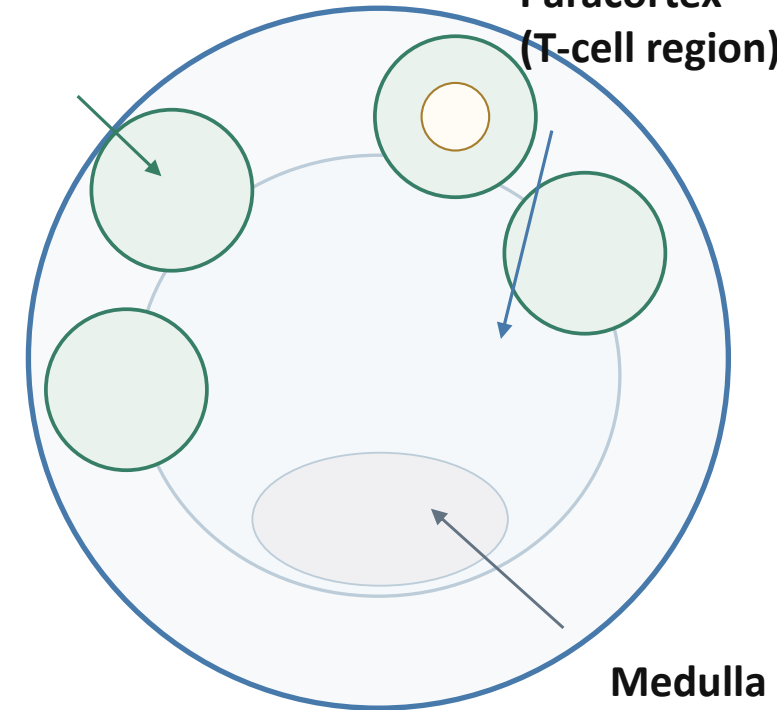
Feature	Conventional DC	Follicular DC
Usual zone	Paracortex	Follicle / germinal center
Principal interaction	Naive T cell	B cell
Source role	T-cell priming	Humoral response

Cortex, paracortex and medulla provide orientation

- Cortical follicles and adjacent paracortex are different lymphocyte compartments.
- The medulla lies deeper within the lymph node.
- A schematic cross-section can orient these regions but is not histologic evidence.

**Cortical B-cell
Follicles**

**Paracortex
(T-cell region)**



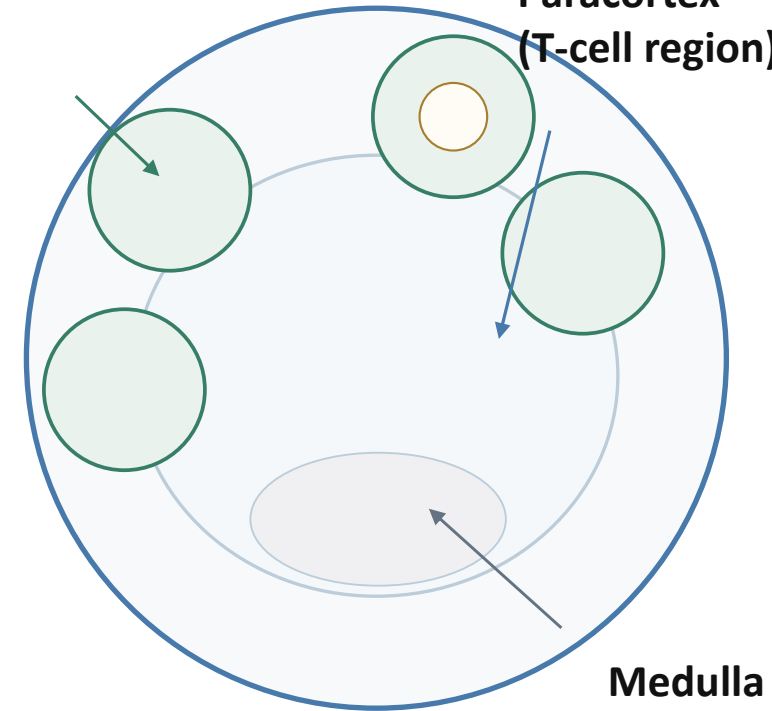
Simplified lymph-node compartment schematic—not an H&E section

Lymph-node zoning links structure with function

- Antigen travels into a node from peripheral tissue.
- T cells scan presented antigen in the paracortex.
- B cells occupy follicles and may form germinal centers after responding.

**Cortical B-cell
Follicles**

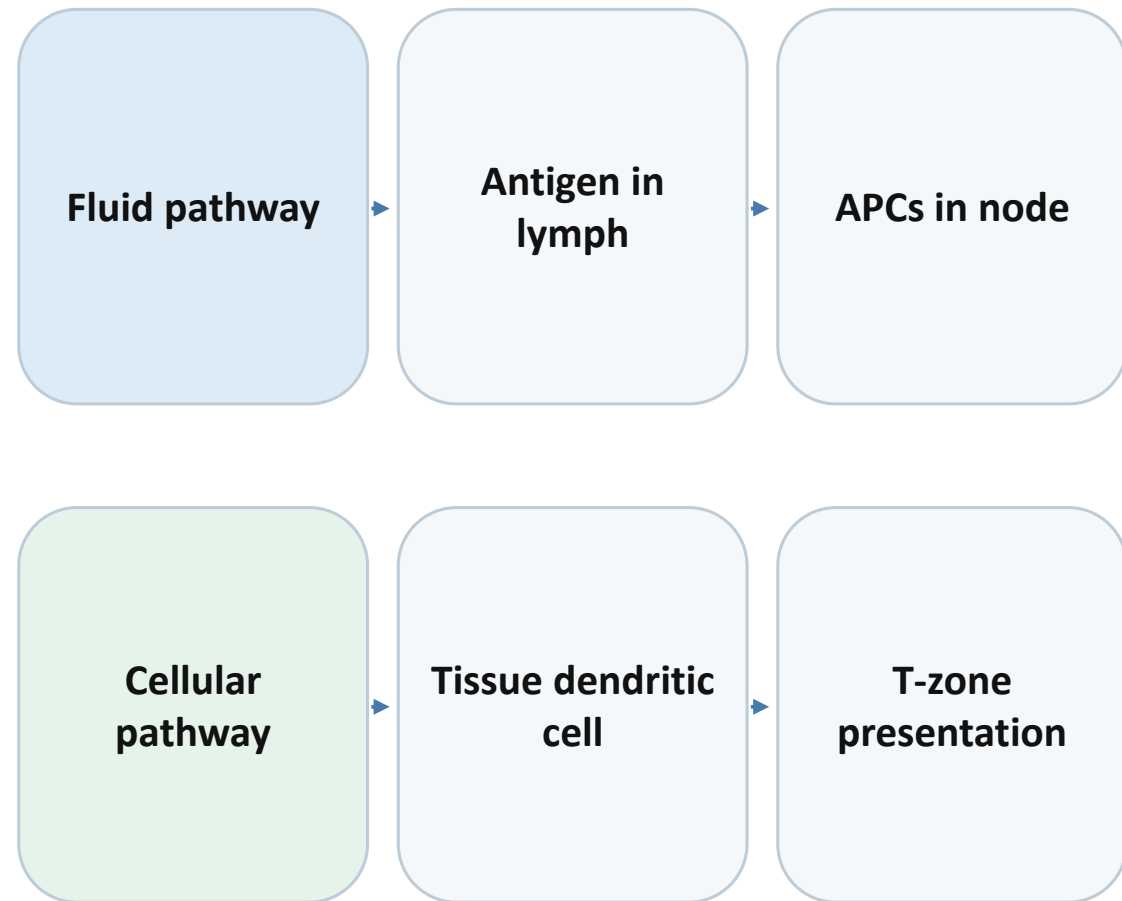
**Paracortex
(T-cell region)**



Simplified lymph-node compartment schematic—not an H&E section

A node integrates two principal antigen-delivery modes

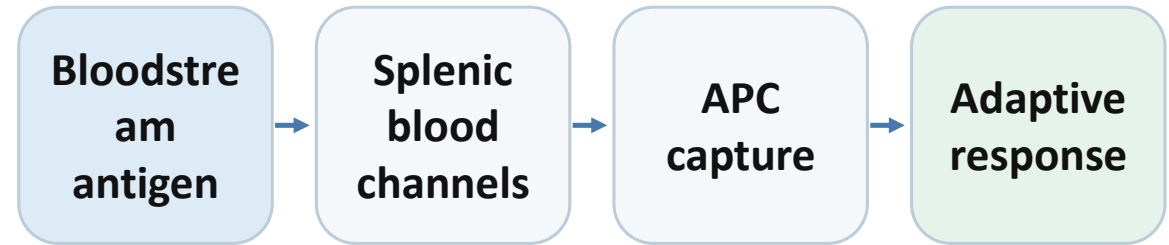
- Lymph transports antigen from peripheral sites.
- Migrating dendritic cells carry acquired antigens from tissues.
- The node combines antigen delivery with organized T/B lymphocyte populations.



Parallel pathways · schematic

The spleen monitors the blood rather than lymph

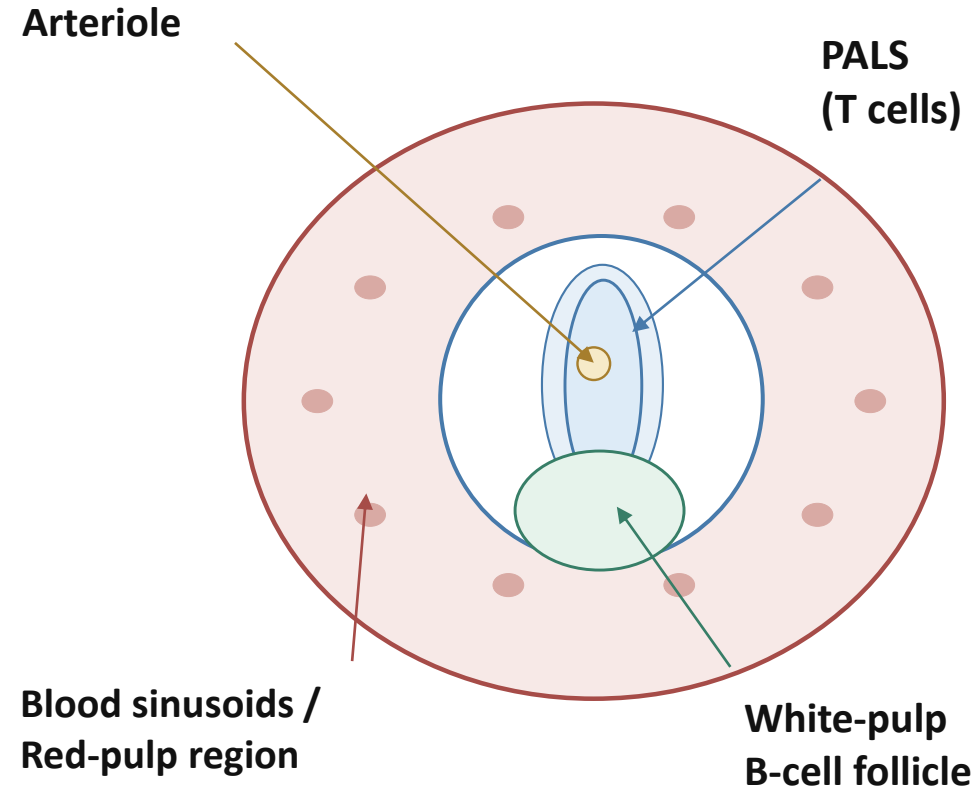
- Blood-borne microbial antigens are intercepted in the spleen.
- The organ is a functional counterpart to nodes for blood-derived antigen.
- Its macrophage- and DC-associated sinusoids contribute to antigen trapping.



Functional sequence · schematic

Sinusoids expose incoming blood to immune cells

- Blood entering the spleen passes through a network of sinusoids.
- Macrophages and dendritic cells line these channels in the source description.
- They trap blood-borne microbial antigens for initiation of adaptive immunity.



Highly simplified spleen white-pulp schematic; Not tissue morphology

Macrophages and DCs cooperate in splenic surveillance

- Both cell populations contribute to capture of blood-borne antigens.
- Dendritic cells link capture to T-cell activation.
- Macrophages also perform antigen presentation and microbial disposal.

Dendritic cell

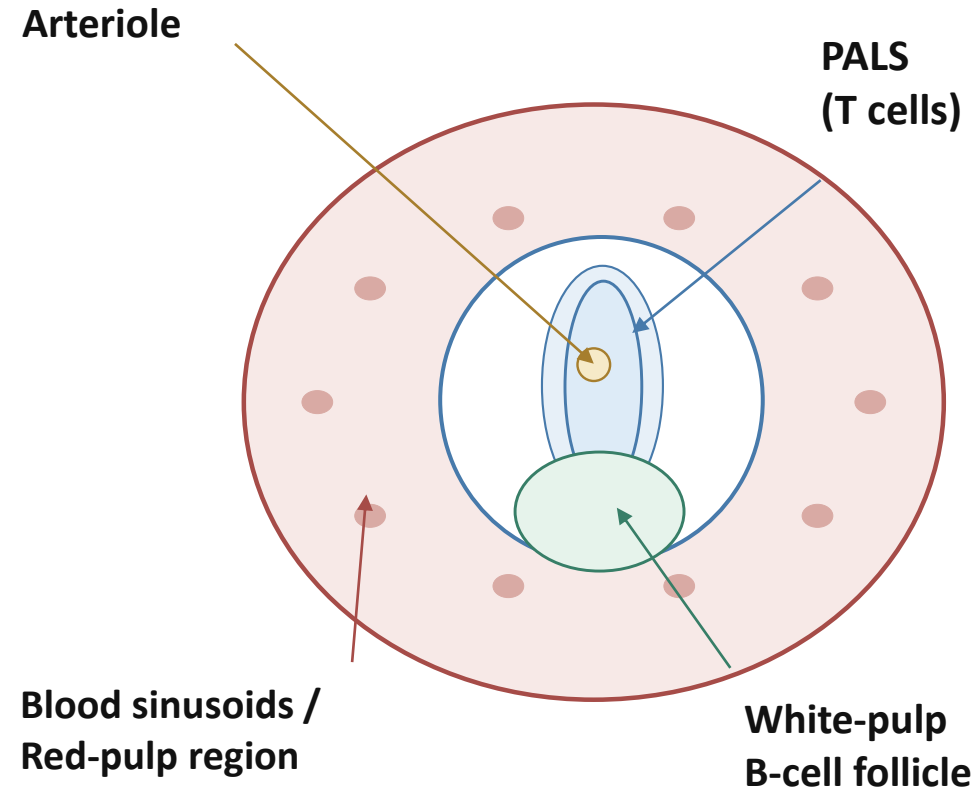
Antigen capture and
T-cell presentation

Macrophage

Antigen capture,
presentation and
ingestion

Splenic white pulp organizes lymphocytes

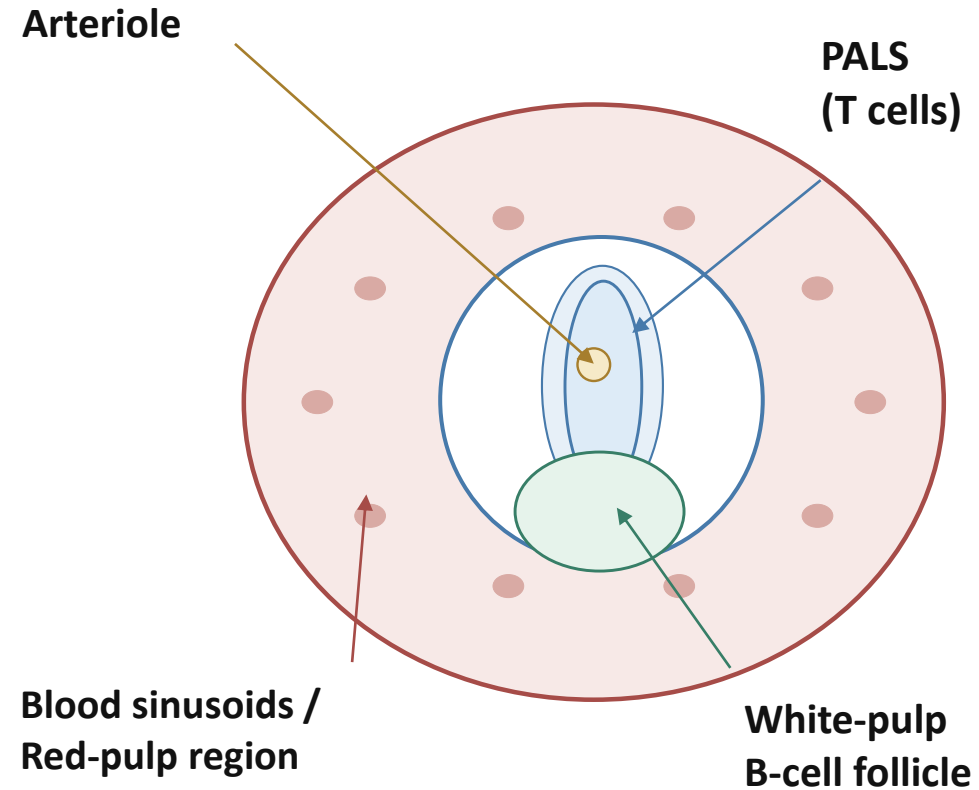
- T lymphocytes collect in periarteriolar lymphoid sheaths.
- B lymphocytes inhabit white-pulp follicles.
- These are specialized zones for responses to antigens delivered by blood.



Highly simplified spleen white-pulp schematic; Not tissue morphology

Periarteriolar lymphoid sheaths are T-cell zones

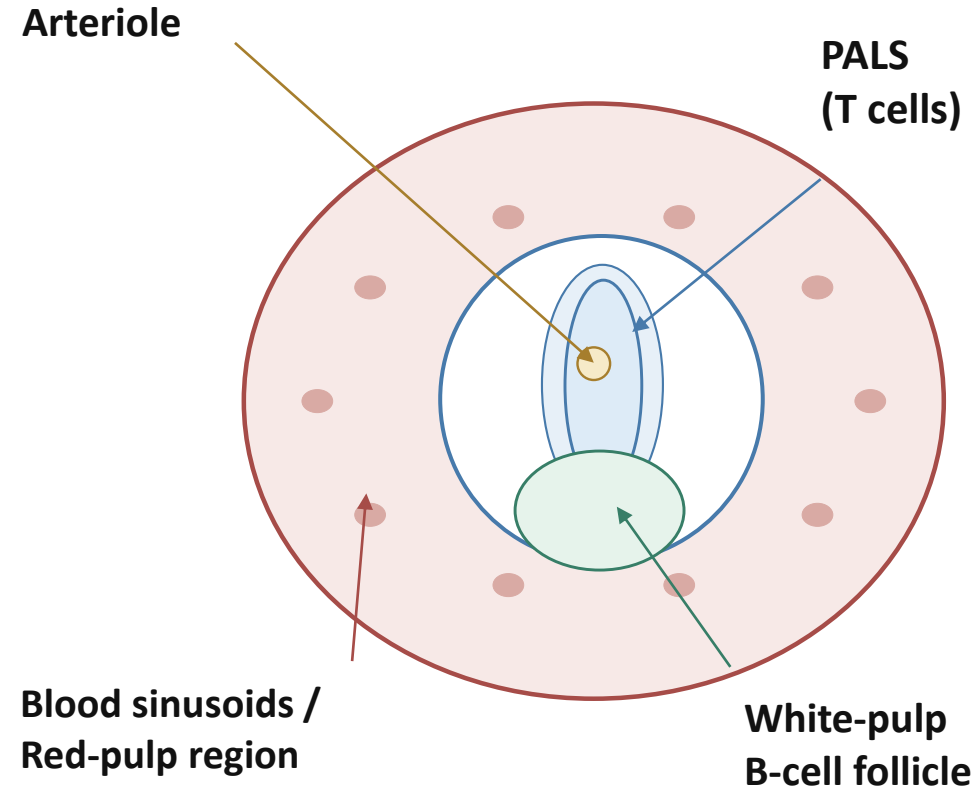
- T cells surround small arterioles in a sheath-like distribution.
- The distribution gives this white-pulp component its name: PALS.
- It parallels the T-cell-rich paracortex of a lymph node.



Highly simplified spleen white-pulp schematic; Not tissue morphology

Splenic follicles contain the B-cell compartment

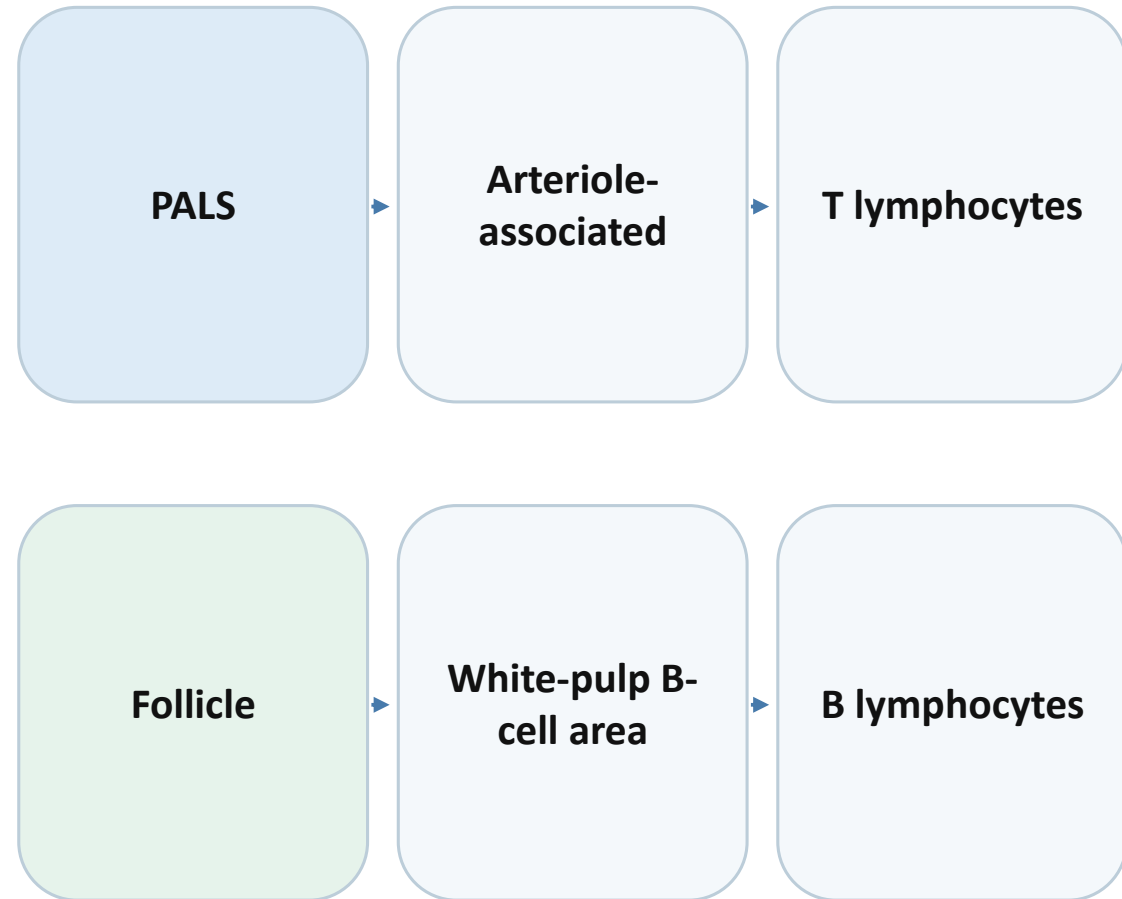
- Splenic B cells reside in follicles analogous to nodal follicles.
- Follicles form part of splenic white pulp.
- Their separation from PALS maintains a spatial B/T division.



Highly simplified spleen white-pulp schematic; Not tissue morphology

Splenic T- and B-cell areas are complementary

- Antigen capture in splenic blood channels occurs near immune-cell-rich tissue.
- PALS position T cells around arterioles.
- Follicles position B cells for humoral responses.



Parallel pathways · schematic

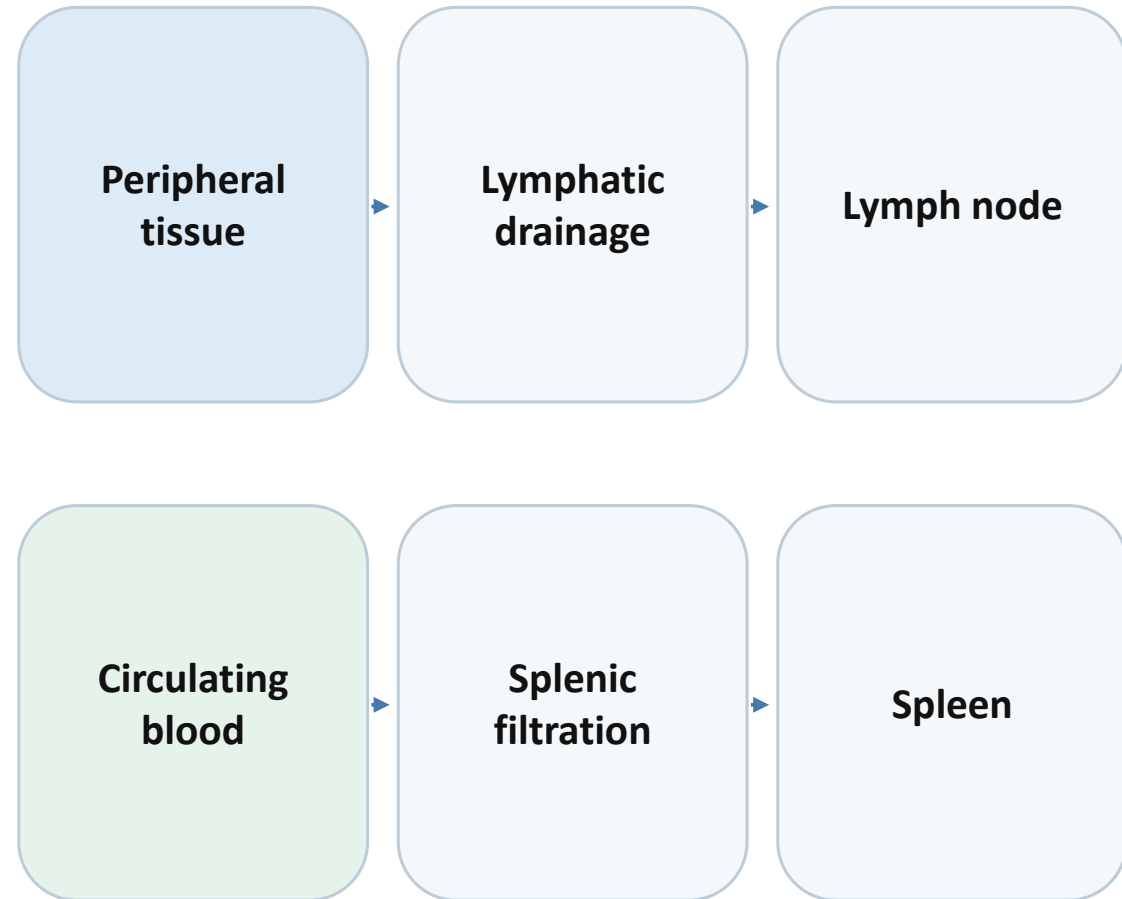
Nodes and spleen differ primarily in what they sample

- Nodes: Antigens entering lymphatics from peripheral tissues.
- Spleen: Antigens circulating through the bloodstream.
- Both concentrate antigen and organize T/B lymphocytes.

Comparison	Lymph node	Spleen
Incoming antigen	Tissue / lymph	Blood
T-cell location	Paracortex	PALS
B-cell location	Cortical follicle	White-pulp follicle

The same microbial antigen may follow distinct routes

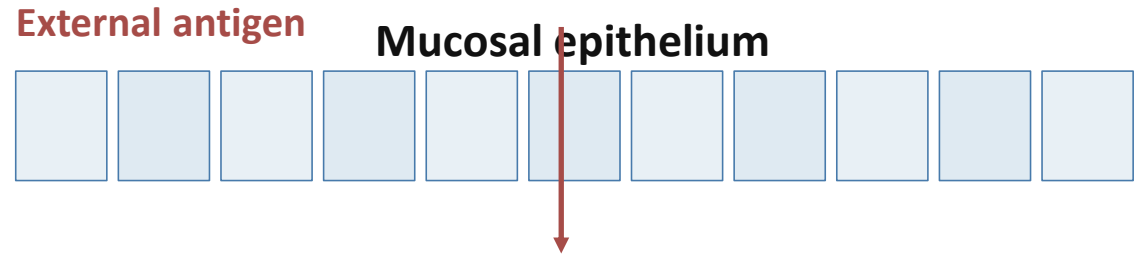
- An antigen localized in tissue is commonly carried through lymphatic drainage.
- A blood-circulating antigen is sampled by the spleen.
- Organ selection follows the antigen's anatomical distribution, not a fixed microbial label.



Parallel pathways · schematic

Mucosal and cutaneous systems guard barriers

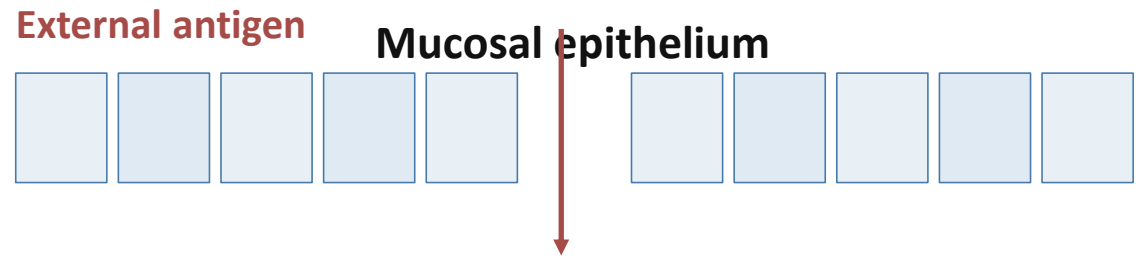
- Lymphoid tissue lies beneath epithelial surfaces of skin and mucosa.
- Gut and respiratory mucosa are major mucosal immune locations.
- These systems respond to antigens that cross breaches in epithelia.



Entry across epithelium → local antigen sampling and response

The epithelial barrier determines initial antigen access

- Intact epithelial surfaces physically separate external materials from immune tissue.
- When antigen crosses the barrier, underlying immune cells can respond.
- This spatial arrangement applies to cutaneous as well as mucosal sites.

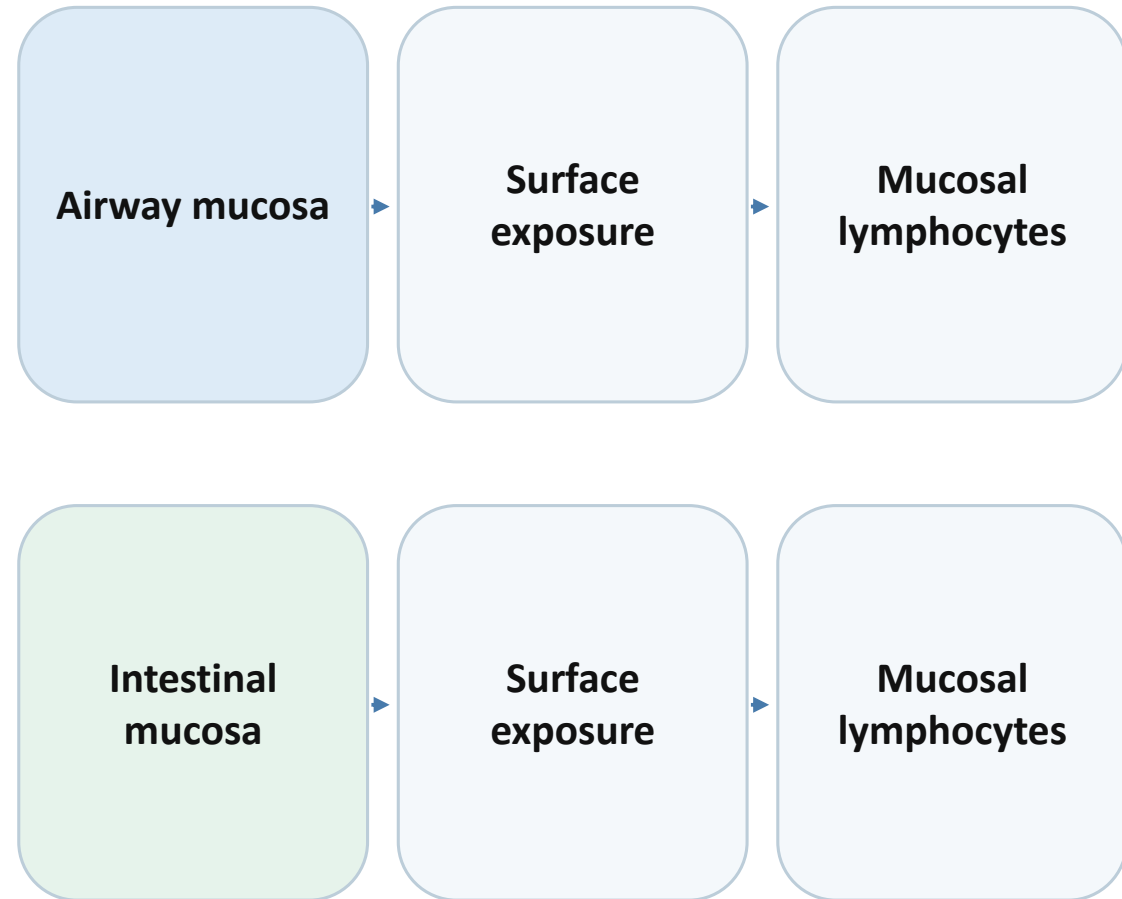


Subepithelial lymphoid cells / antigen-presenting cells

Entry across epithelium → local antigen sampling and response

Respiratory and gastrointestinal mucosa are immune sites

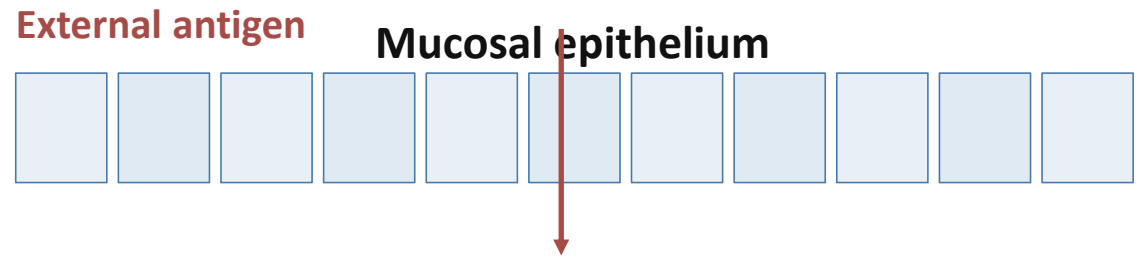
- Both tracts expose large epithelial surfaces to environmental material.
- Lymphoid cells associated with their mucosa can respond to entering antigens.
- The anatomical association distinguishes mucosal tissue from spleen and nodes.



Parallel pathways · schematic

Pharyngeal tonsils are organized mucosal tissue

- Pharyngeal tonsils are anatomically defined components of the mucosal immune system.
- Their position relates them to an epithelial antigen-entry interface.
- They illustrate that mucosal immunity includes discrete organized structures.

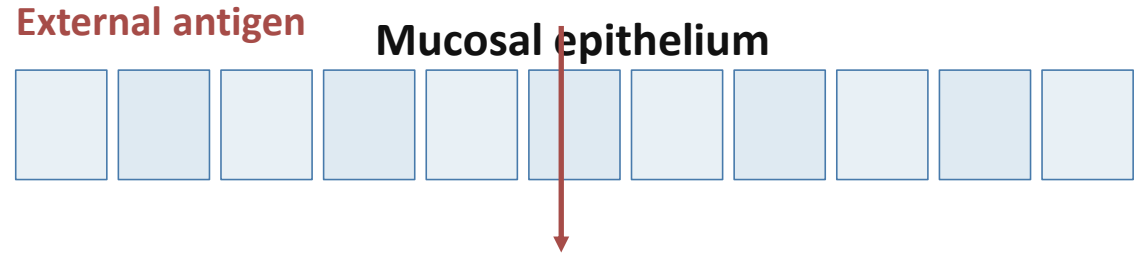


Subepithelial lymphoid cells / antigen-presenting cells

Anatomically defined mucosal tissue: Pharyngeal tonsil

Peyer patches are discrete intestinal lymphoid tissue

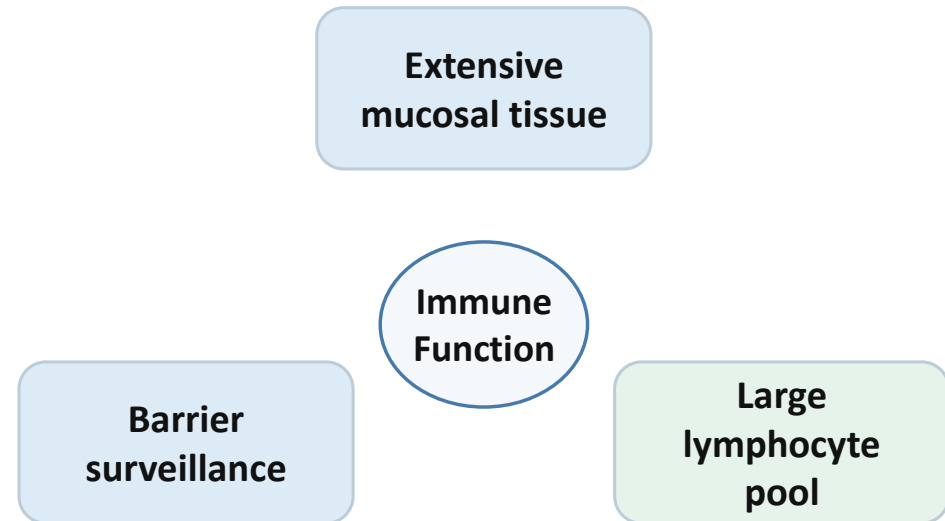
- Peyer patches are organized mucosal lymphoid tissue in the intestine.
- They exemplify lymphoid architecture associated with the gut barrier.
- They belong to the mucosal rather than primary lymphoid category.



Organized intestinal lymphoid tissue: Peyer patches

Mucosal tissues contain many lymphocytes

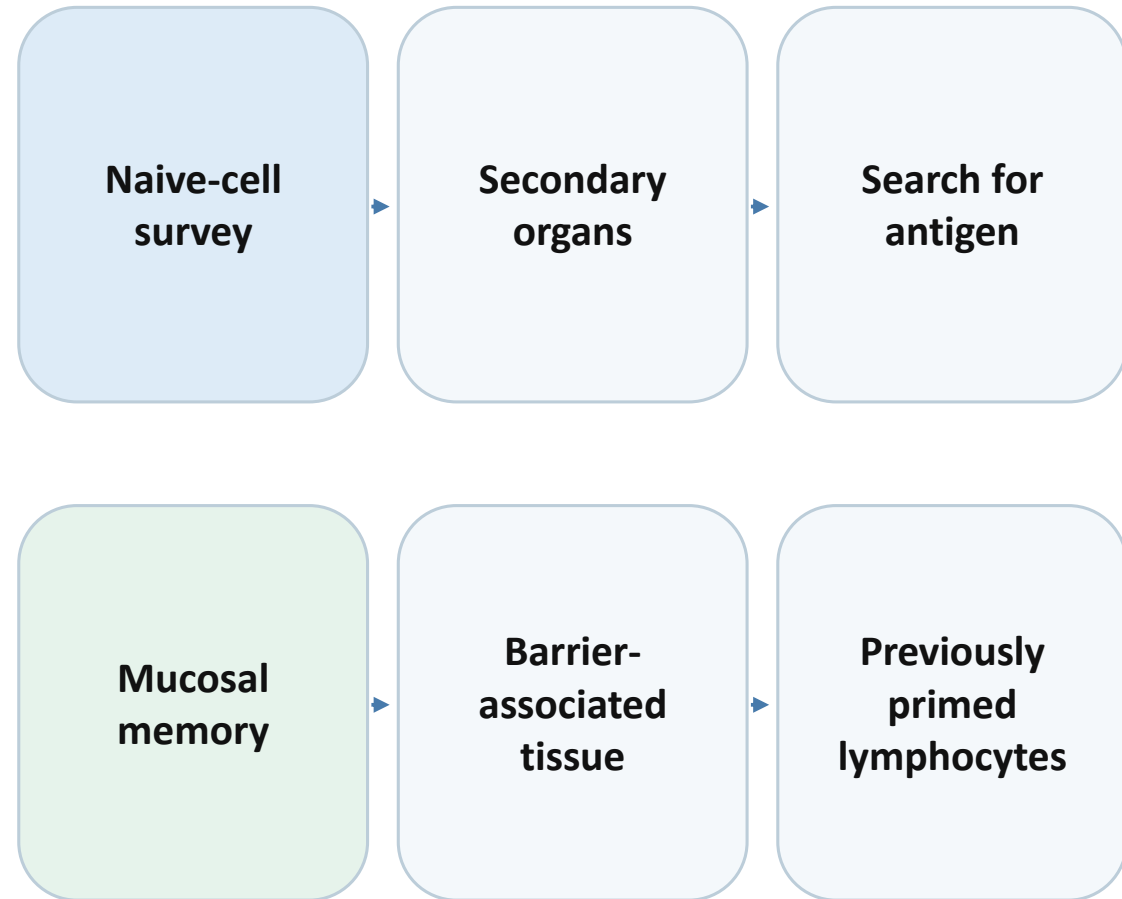
- A large proportion of the body's lymphocytes may be within mucosal tissues.
- This reflects the substantial extent of mucosal surfaces and tissue.
- The distribution underscores why mucosal immune responses are anatomically important.



Conceptual relationship · schematic

Memory cells are abundant at mucosal sites

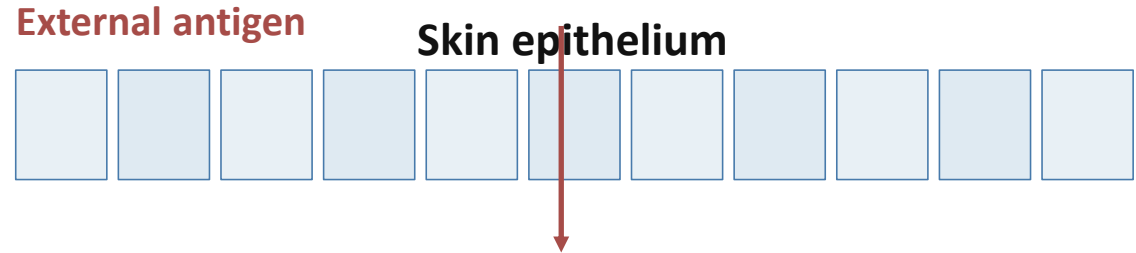
- Many lymphocytes resident in mucosal tissues have memory phenotypes.
- Their presence is compatible with repeated environmental antigen exposure.
- The source notes their prevalence, without specifying a numerical proportion.



Parallel pathways · schematic

Cutaneous immune tissue is situated under the skin

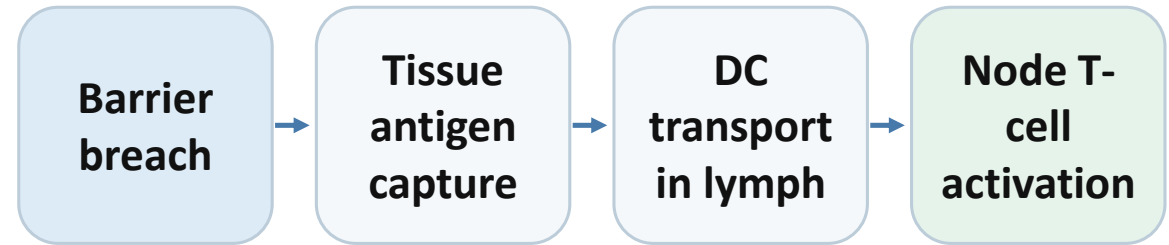
- Cutaneous lymphoid components lie beneath the skin epithelium.
- They respond to antigens gaining access through epithelial breaches.
- Epidermal Langerhans cells are a dendritic-cell population relevant to antigen sampling.



Entry across epithelium → local antigen sampling and response

Epithelial capture and lymphoid activation are linked

- Dendritic cells at or below epithelial entry sites capture antigens.
- The cells may migrate in lymph to draining lymph nodes.
- Node T-cell zones provide the subsequent antigen-presentation environment.



Functional sequence · schematic

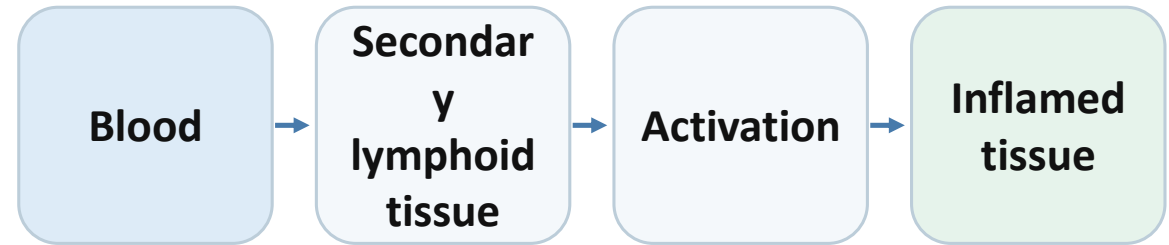
Peripheral immune organs are tailored to antigen routes

- Nodes are optimized for lymph-borne antigens.
- Spleen surveys blood-borne antigens.
- Barrier-associated tissues respond beneath mucosal and cutaneous epithelium.

Site	Anatomical input	Principal context
Lymph node	Lymphatic drainage	Tissue-derived antigen
Spleen	Circulating blood	Blood-borne antigen
Barrier tissue	Across epithelium	Mucosal or skin response

Lymphocyte recirculation connects immune locations

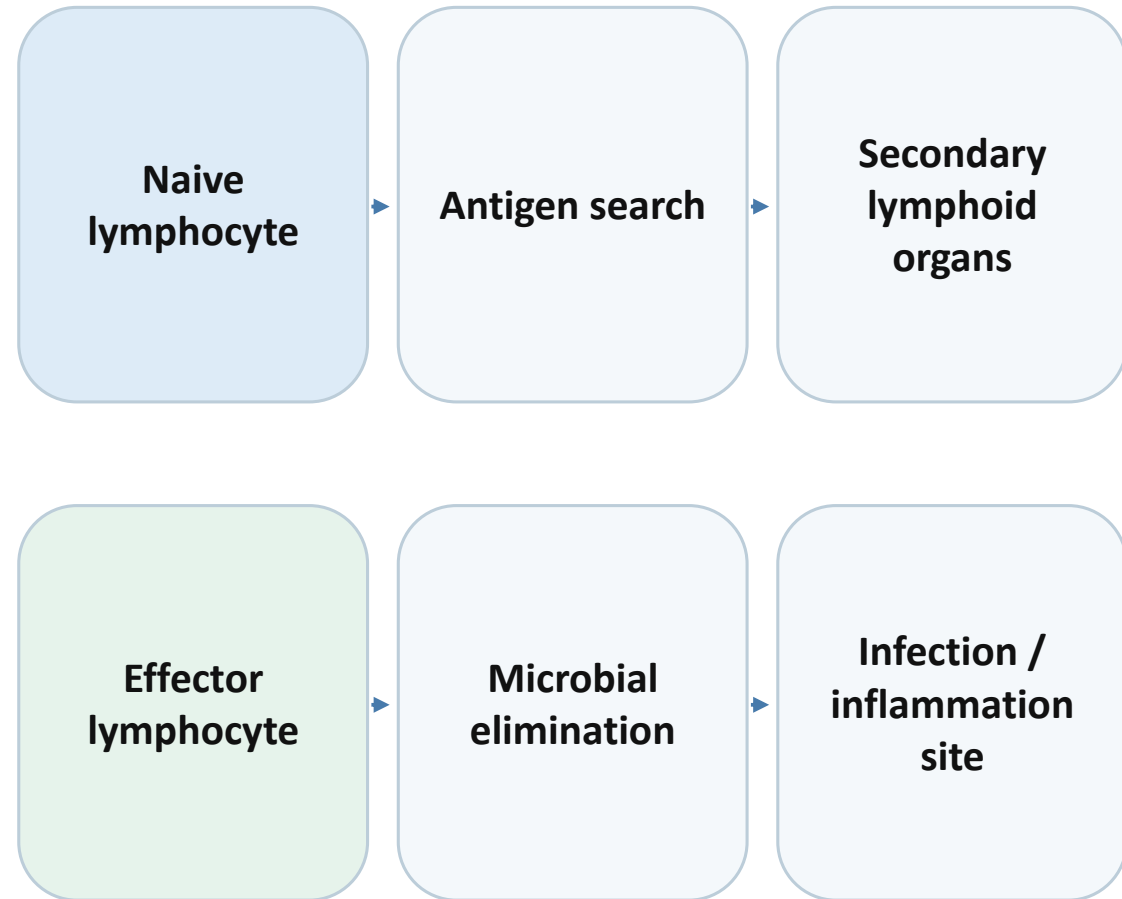
- Lymphocytes continuously move between blood and specific tissues.
- Naive lymphocytes pass through secondary lymphoid organs.
- Effector cells can travel to sites where infection and inflammation are present.



Functional sequence · schematic

Naive and effector lymphocytes follow different goals

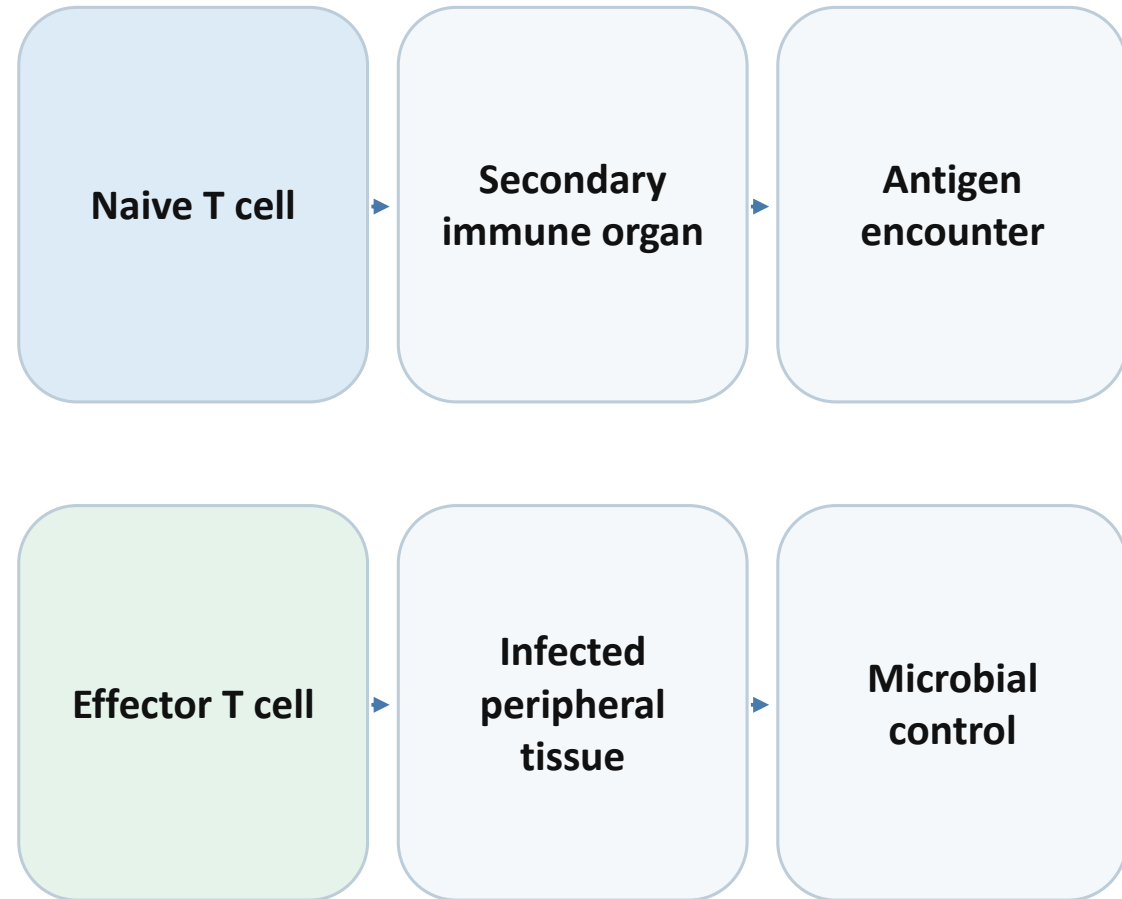
- Naive lymphocytes move through organs where antigen is concentrated.
- Effector lymphocytes migrate to sites requiring microbial elimination.
- Circulation is organized around cell function rather than random redistribution.



Parallel pathways · schematic

T-cell recirculation is functionally essential

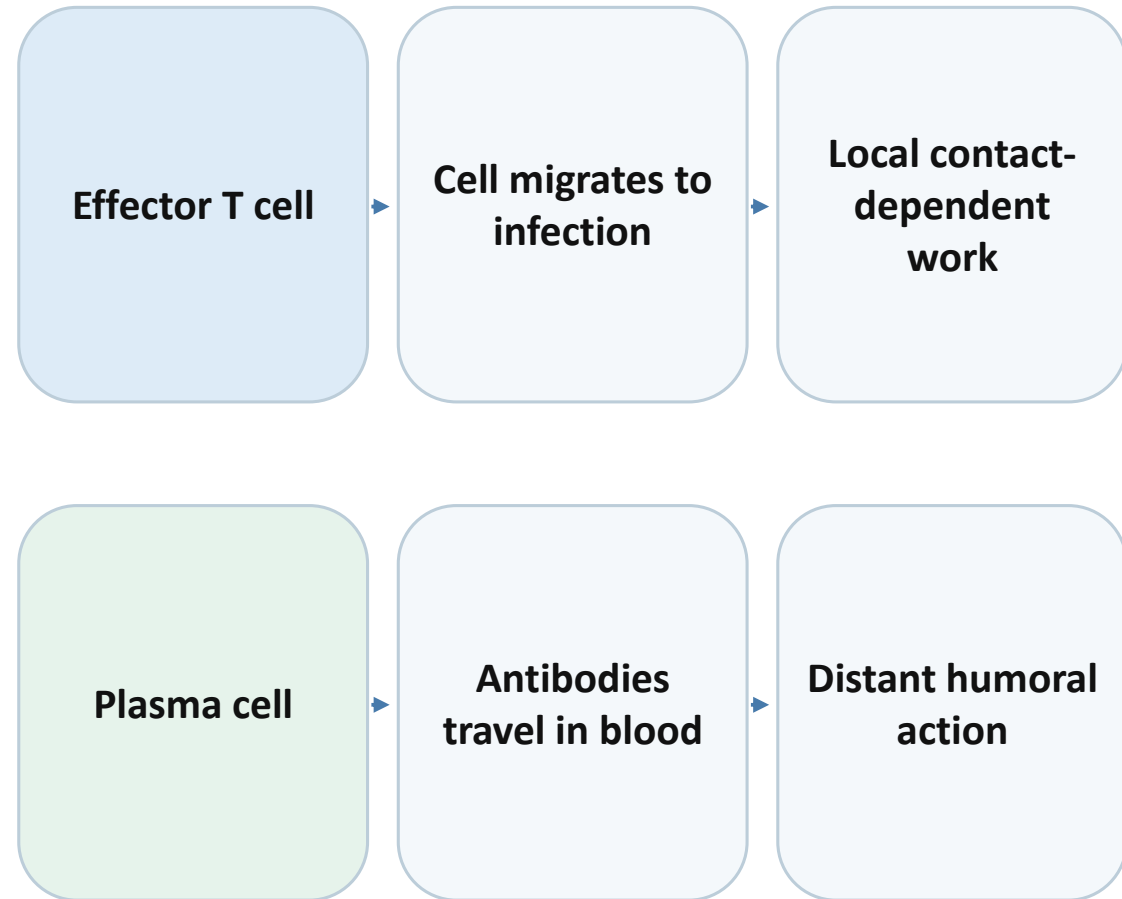
- Naive T cells must search secondary-organ sites for presented antigen.
- Effector T cells need access to infected tissues to act on microbes.
- This is why the source places particular emphasis on T-cell recirculation.



Parallel pathways · schematic

Plasma cells use a different distribution strategy

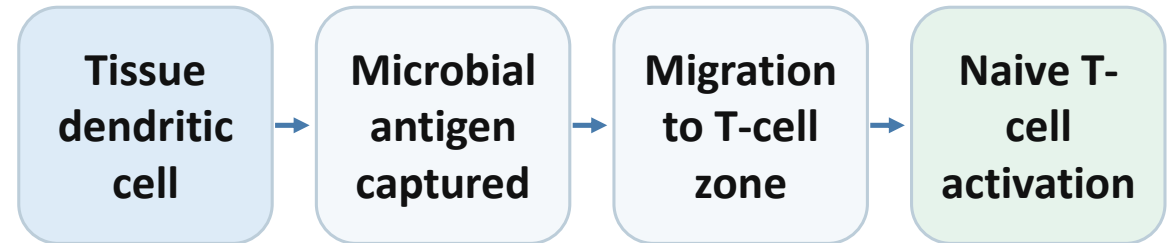
- Plasma cells can remain in lymphoid organs and bone marrow.
- They secrete antibodies that circulate in blood to distant sites.
- Unlike effector T cells, antibody-producing cells need not reach each infected tissue.



Parallel pathways · schematic

Dendritic cells are positioned for naive T-cell priming

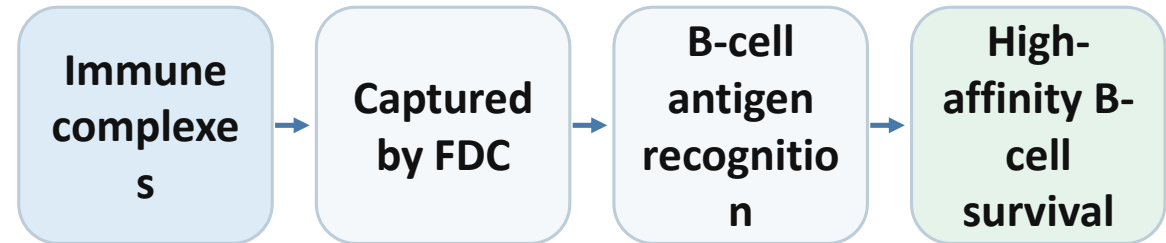
- They are frequent at epithelial and interstitial sites of antigen entry.
- Microbial signals promote their movement to lymphoid T-cell zones.
- They display protein-derived antigen with abundant MHC and activation molecules.



Functional sequence · schematic

Follicular dendritic cells support B-cell responses

- FDCs are specialized fibroblasts within follicles and germinal centers.
- They retain antibody- or complement-associated antigen using Fc and C3b receptors.
- Their interaction supports selection of B cells with higher antigen affinity.



Functional sequence · schematic

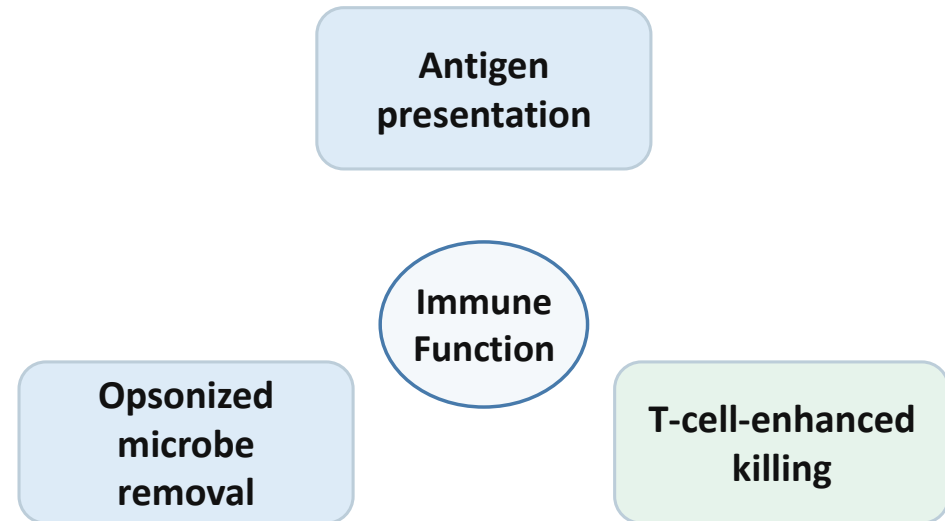
Conventional DCs and FDCs are fundamentally different

- Conventional DCs present processed antigens to T lymphocytes.
- FDCs retain antigen complexes and make them available to B lymphocytes.
- Despite their names, FDCs are not the cells that prime naive T cells.

Aspect	Conventional dendritic cell	Follicular dendritic cell
Main location	T-cell area	Follicle / germinal center
Key function	T-cell antigen presentation	Antigen retention for B cells
Identity	Myeloid APC	Specialized fibroblast

Macrophages contribute at several immune stages

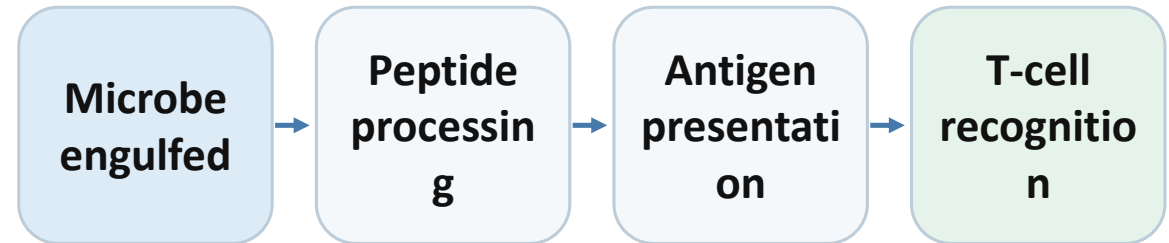
- Ingestion and processing allow macrophages to present peptide antigens to T cells.
- T-cell activation can increase macrophage killing of ingested microbes.
- Macrophages also ingest microbes coated with IgG or C3b.



Conceptual relationship · schematic

A macrophage can present ingested antigen to a T cell

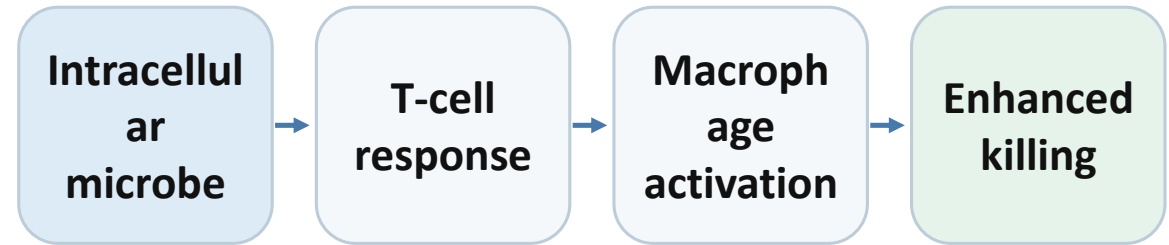
- Macrophages phagocytose microbes or protein antigens.
- Processed peptide fragments can be presented to T lymphocytes.
- This connects innate microbial ingestion with adaptive immune recognition.



Functional sequence · schematic

T lymphocytes can amplify macrophage microbicidal action

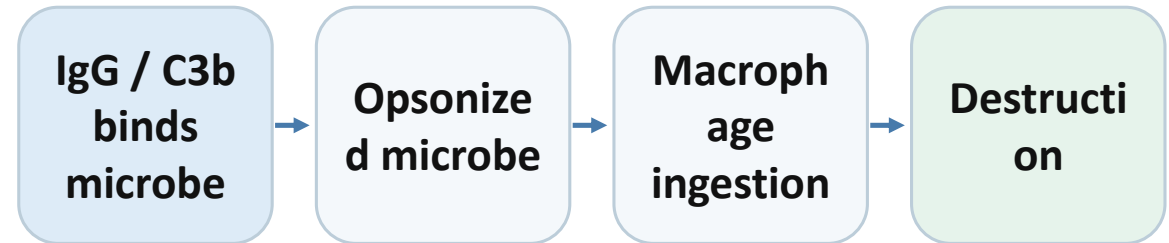
- Certain cell-mediated responses are directed against intracellular microbes.
- Activated T cells stimulate macrophages.
- Activated macrophages are more effective at killing ingested organisms.



Functional sequence · schematic

Opsonization improves macrophage phagocytosis

- Antibody IgG or complement fragment C3b may coat a microbe.
- Macrophages efficiently ingest and destroy coated microbes.
- This is an effector link between humoral immunity and innate phagocytes.



Functional sequence · schematic

Application: A microbe enters damaged skin

- A skin breach introduces microbial antigen into underlying tissue.
- Dendritic cells and lymph drainage can convey antigen toward a regional node.
- A draining lymph node is the expected major site of initiating an adaptive response.

Reasoning prompt

Antigen enters a peripheral tissue through damaged skin. Which secondary organ first concentrates the draining antigen?

Anatomical inference

The regional draining lymph node—tissue antigens reach it via lymphatic drainage and/or migrating DCs.

Application: Microbial antigen circulates in blood

- The anatomic route is blood, not lymph from a single tissue site.
- Splenic macrophages and dendritic cells encounter circulating antigen.
- The spleen is the relevant organ for blood-borne adaptive immune initiation.

Reasoning prompt

A microbial antigen is distributed through the bloodstream. Which peripheral organ is anatomically specialized to sample it?

Anatomical inference

The spleen—splenic blood channels expose circulating antigens to macrophages and dendritic cells.

Application: A follicle develops a pale center

- A responding B-cell follicle may form a central germinal center.
- Follicular dendritic cells support B-cell responses at this site.
- A follicular pattern should not be confused with the adjacent T-cell-rich paracortex.

Reasoning prompt

A schematic lymph-node follicle now contains a central germinal center. Which lymphocyte compartment is responding?

Anatomical inference

The B-cell follicle—germinal-center formation is associated with recent follicular antigen response.

Application: Identify the T-cell-rich nodal region

- The cortex contains B-cell follicles.
- The paracortex is rich in T cells and conventional dendritic cells.
- A location adjacent to follicles therefore points to the T-cell compartment.

Reasoning prompt

An antigen-presenting dendritic cell interacts with a naive T cell beside cortical follicles. Name the nodal region.

Anatomical inference

Paracortex—the lymph-node T-cell zone, adjacent to the cortical B-cell follicles.

Application: Why plasma cells need not migrate

- Plasma cells can remain in bone marrow or lymphoid organs.
- Their secreted antibodies circulate to distant sites via blood.
- Effector T cells, in contrast, must often reach infected tissue.

Reasoning prompt

A plasma cell stays in marrow despite an infection elsewhere. Why can it still contribute to host defense?

Anatomical inference

It secretes antibodies distributed through blood;
The cell itself need not reach the site of infection.

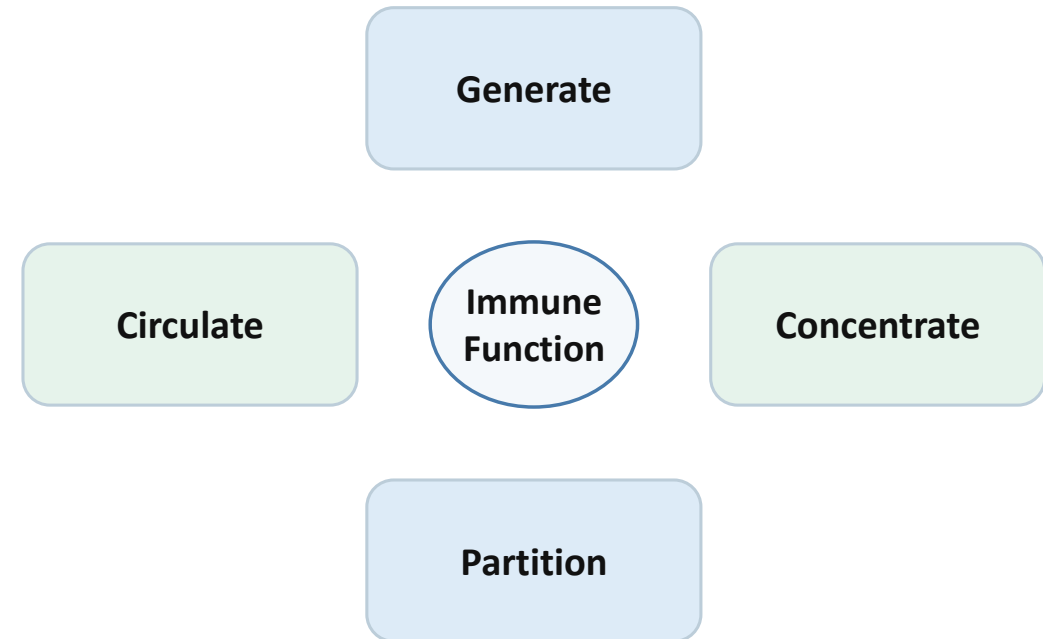
Organ, input and lymphocyte territory must be linked

- Node: Lymphatic input; Follicles contain B cells and paracortex contains T cells.
- Spleen: Blood input; Follicles contain B cells and PALS contains T cells.
- Barrier tissue: Subepithelial sampling, including organized mucosal structures.

Tissue	Input route	Characteristic T/B arrangement
Lymph node	Lymphatic	Paracortex / cortical follicles
Spleen	Blood	PALS / white-pulp follicles
Mucosa or skin	Barrier epithelium	Subepithelial immune populations

Five principles explain the tissue organization

- Primary tissues generate antigen-responsive T and B lymphocytes.
- Secondary tissues concentrate antigen and surveying naive lymphocytes.
- T- and B-cell neighborhoods organize different phases of immunity.
- Lymph nodes sample lymph; Spleen samples blood; Barriers host local immunity.
- Recirculation delivers naive cells to antigen and effectors to sites of action.



Conceptual relationship · schematic

Source and scope

- Robbins, Cotran & Kumar: Pathologic Basis of Disease. 11th ed. (2026).
- Chapter 6: Diseases of the Immune System—“Tissues of the Immune System,” p. 174–175.
- Immediately preceding “Myeloid Cells” section supplies DC, FDC and macrophage context.
- Anatomical diagrams are original editable teaching schematics, not histologic specimens.

Core source

Primary and
secondary immune
tissues

Adjacent context

Dendritic cells and
macrophages