

Chapter 22

The Lymphatic System

Chapter 22 Outline

- I. Lymphatic System
- II. Immunity
- III. Innate Immunity
- IV. Adaptive Immunity
- V. Immune Interactions
- VI. Immunotherapy
- VII. Acquired Immunity
- VIII. Effect of aging on the lymphatic system & immunity

I. Lymphatic System

I. Lymphatic System

- Includes:
- Lymph
- Lymphatic Vessels
- Lymphatic tissue
- Lymphatic nodules
- Lymph nodes
- Tonsils
- Spleen
- Thymus

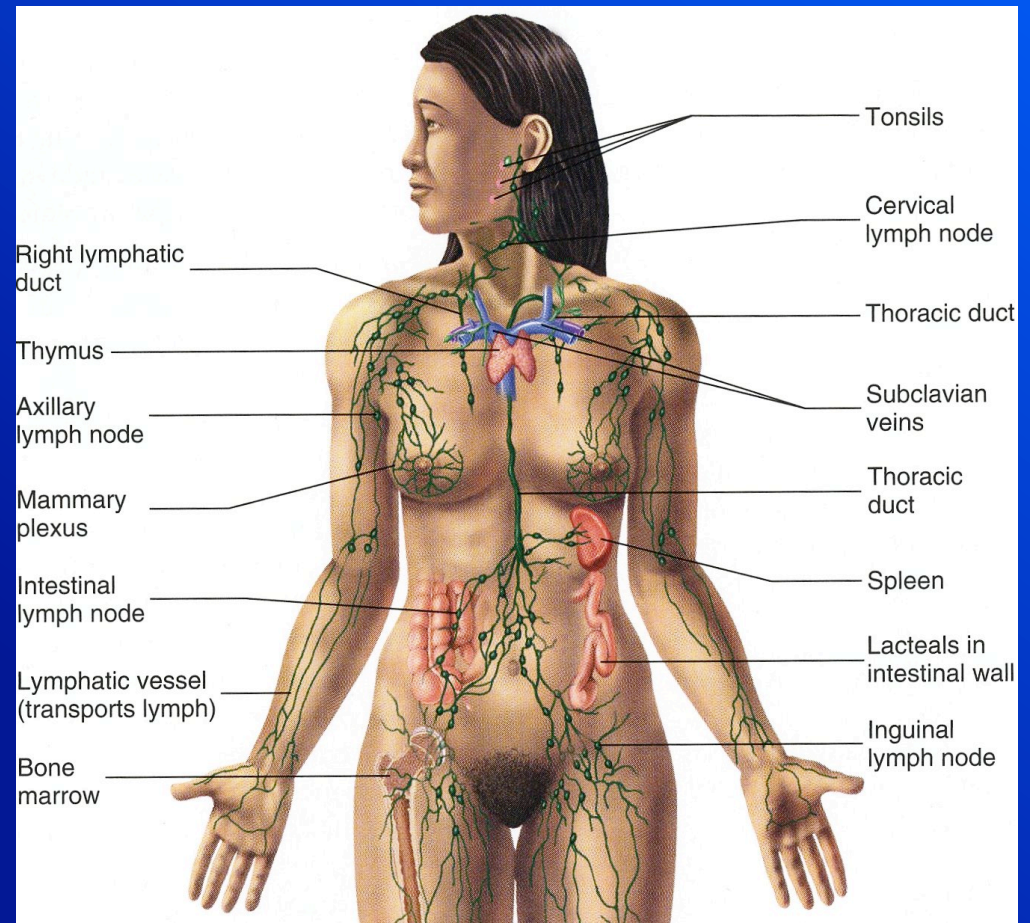


Figure 22.1 page 783

I. Lymphatic System

3 main functions of the lymphatic system

1. Fluid Balance
2. Fat Absorption
3. Defense

1. Fluid Balance

- 90% of the *plasma* fluid that escapes from the capillaries is recovered but the other 10% remains in the tissues as *interstitial fluid*. If it remains in the tissue, it can cause damage and eventual tissue death. Instead this 10% enters the lymphatic capillaries as *lymph* as passes thru the lymphatic vessels back into the blood.
- *Lymph* contains: Water & solute from 2 sources:
 - *Plasma components that were lost with the plasma (nutrients, gases, & some proteins)*
 - *Cell derived substances (hormones, waste products, enzymes)*

I. Lymphatic System

3 main functions of the lymphatic system

1. Fluid Balance
2. Fat Absorption
3. Defense

2. Fat absorption

- In the digestive tract lymphatic vessels called lacteals absorb fats & other substances. These fats go thru the lymphatic system to join the lymphatic circulation.
- **Chyle**: lymph passing thru with a milky appearance because of high fat content

I. Lymphatic System

3 main functions of the lymphatic system

1. Fluid Balance
2. Fat Absorption
3. Defense

3. Defense

- Blood is filtered of microorganisms by the spleen
- Lymph is filtered of microorganisms by the lymph nodes
- Lymphocytes are capable of destroying microorganisms and other foreign substances

I. Lymphatic System

Lymph Vessels

Lymphatic capillaries



Lymphatic Vessels



(Lymph nodes)



Lymphatic vessels



Lymphatic Trunks

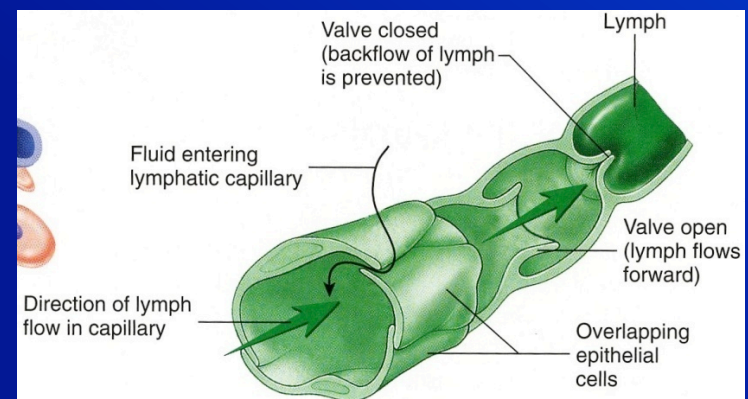
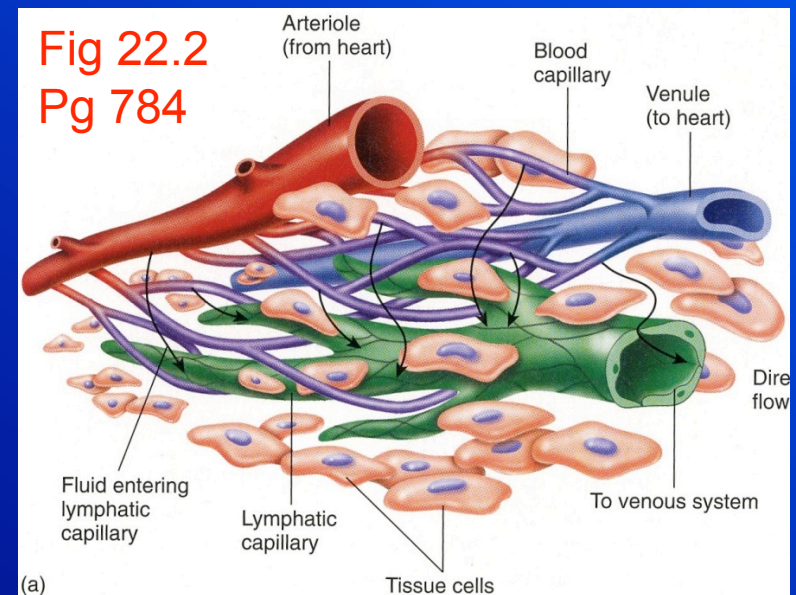
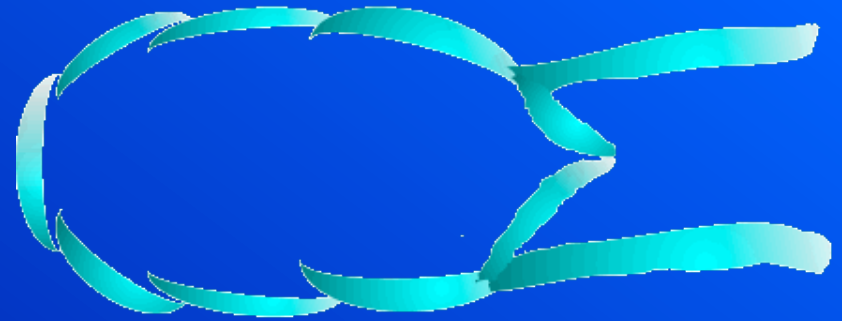


Vein

I. Lymphatic System

Lymphatic Vessels

- Lymphatic capillaries are dead ends that open with an increase in osmotic pressure.
- Simp. Sq. Epi cells of the capillary wall over lap. This does 2 things:
 1. makes them more permeable than capillaries in the cardiovascular system &
 2. Nothing is excluded from the lymph via filtration
 - It also acts as a valve system preventing back flow
- As the pressure in the interstitial fluid increases, it causes valves in capillary to open allowing fluid movement.
- Once fluid is inside of the lymphatic vessel it is called Lymph
- These capillaries are in almost every tissue in the body to drain interstitial fluid.



I. Lymphatic System

Lymphatic Vessels

- Capillaries join to form larger lymphatic vessels that resemble small veins with a middle layer of smooth muscle
- Have a beaded appearance b/c of valves which insure 1 way flow, when it becomes compressed lymph moves from chamber to chamber

Fig 22.2
Pg 784

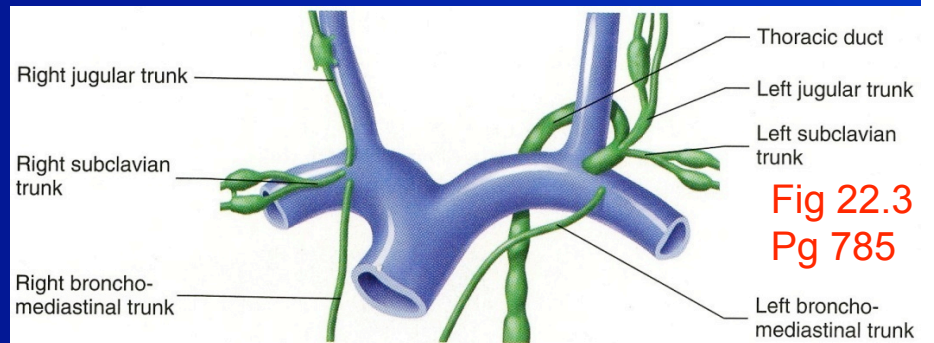
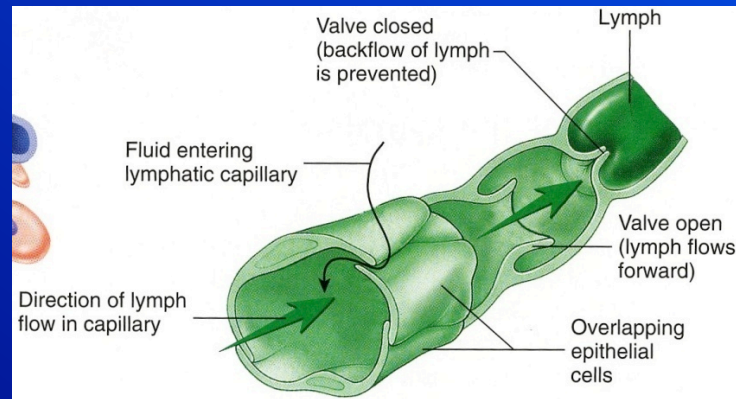
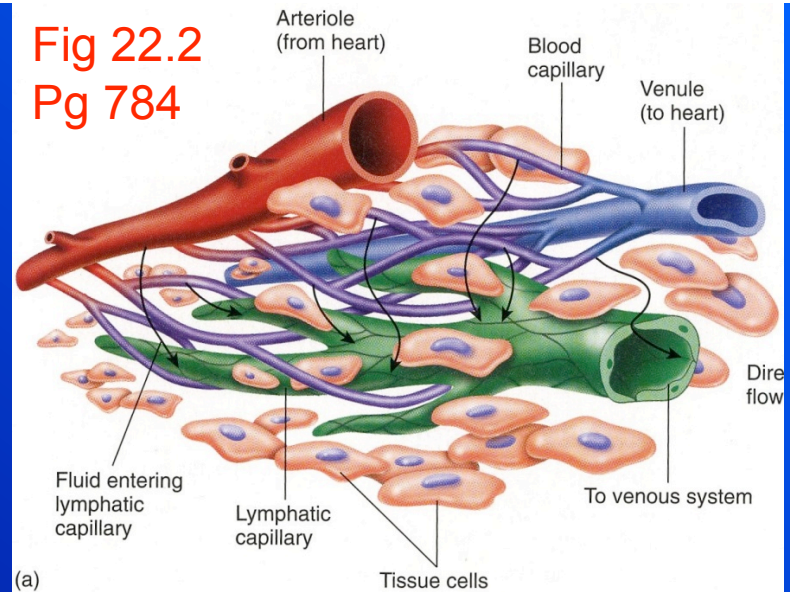


Fig 22.3
Pg 785

3 major mechanisms responsible for lymph movement in vessels:

1. Contraction of lymph vessels

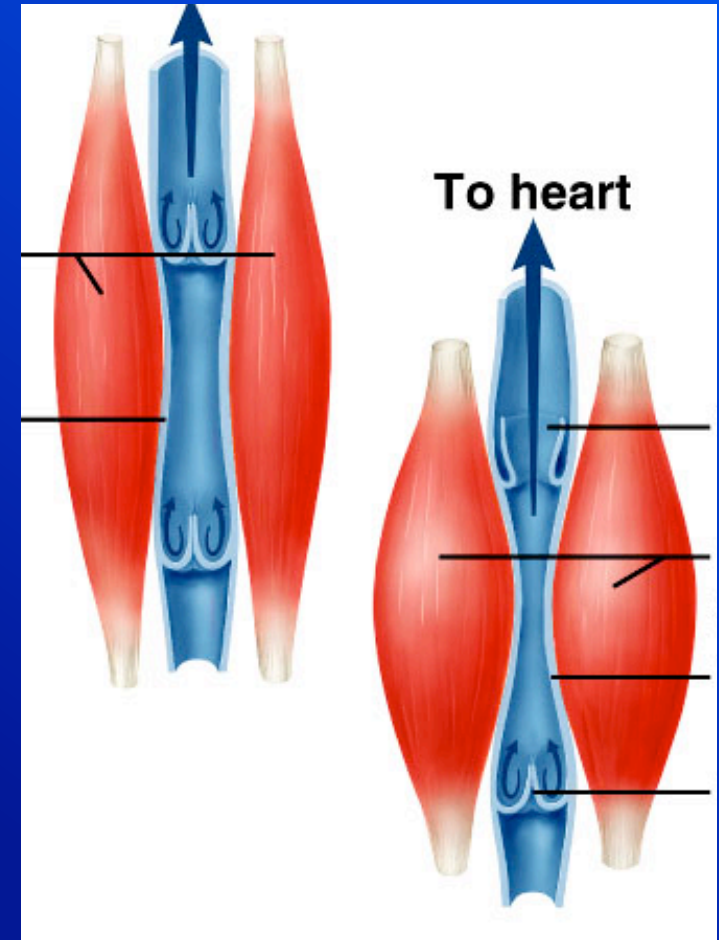
- pacemaker cells cause contraction of smooth muscle in the vessel wall as they fill with lymph advancing lymph to next chamber

2. Contraction of skeletal muscles

- Vessel gets squeezed between contracting muscle & with valves lymph advances

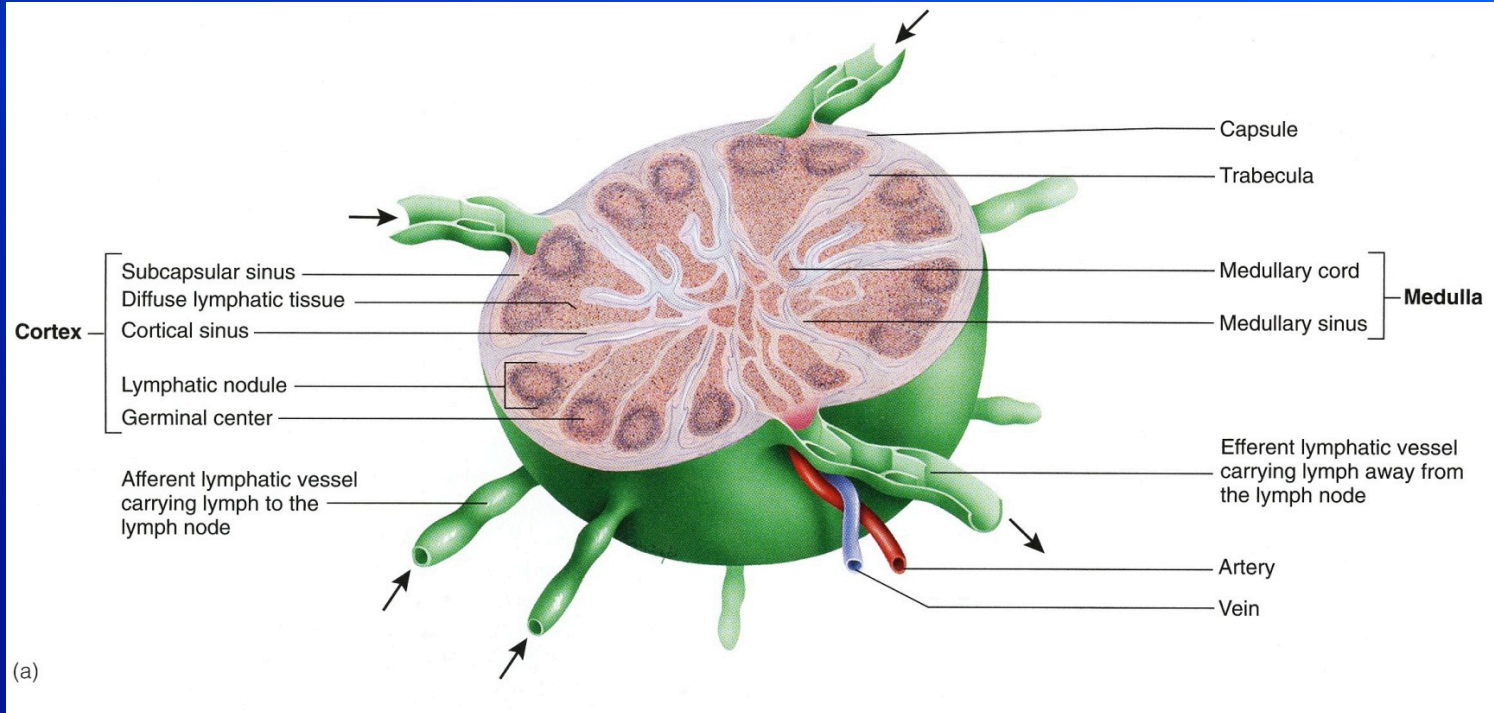
3. Thoracic pressure changes

- Like sucking air from a straw to draw up liquid, the pressure changes in the thoracic cavity suck-up lymph from vessels

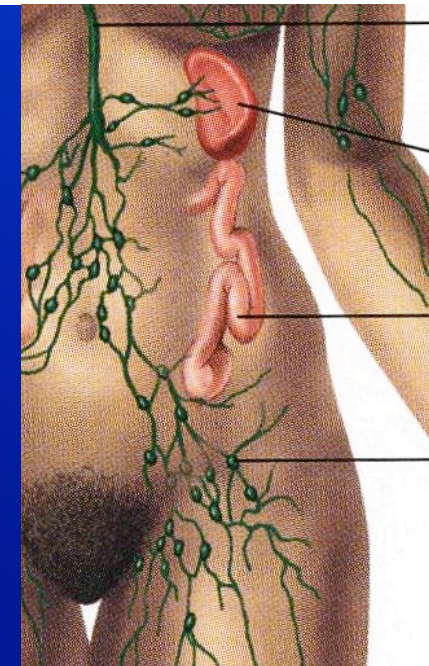


I. Lymphatic Vessels

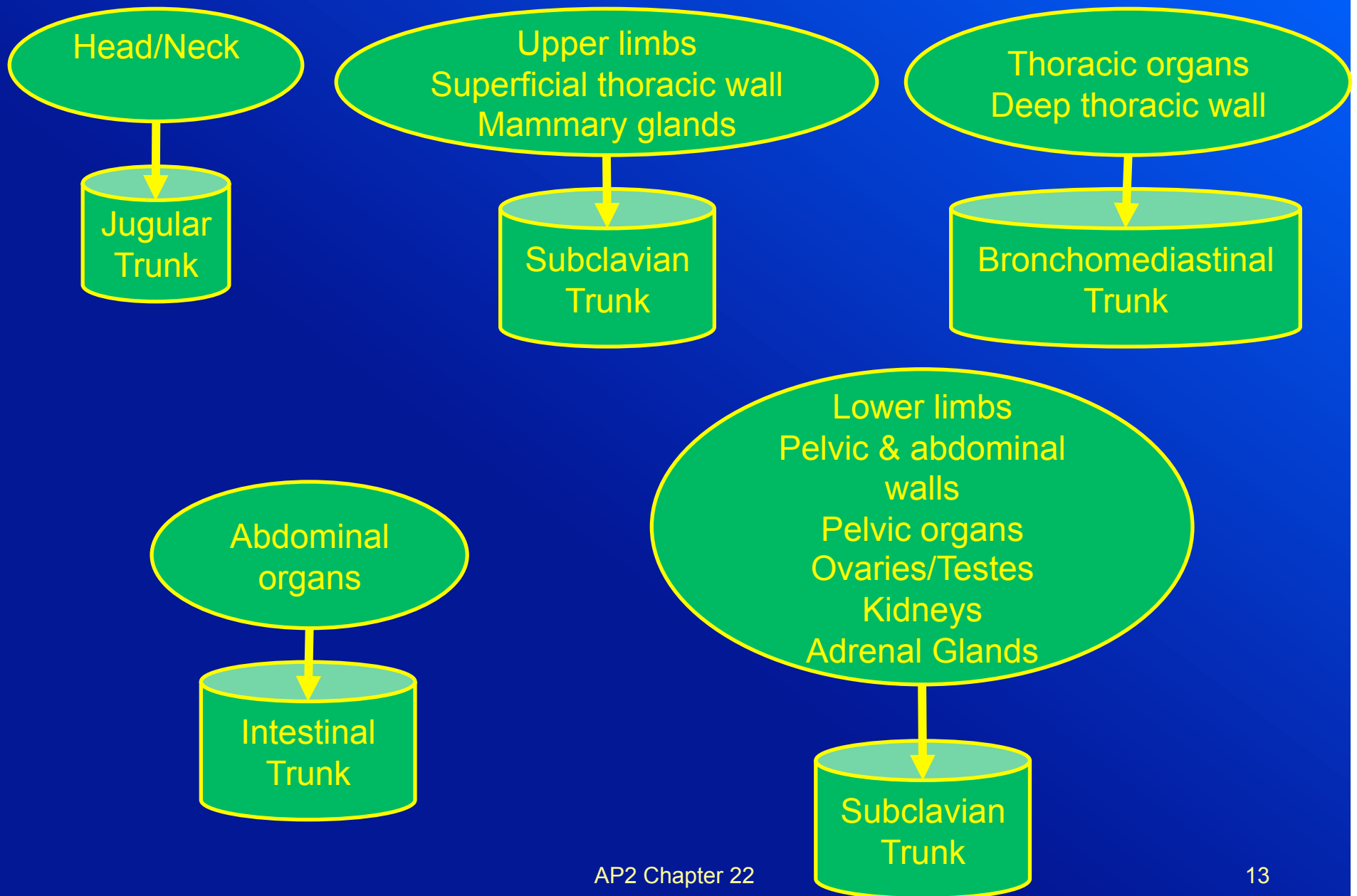
Lymph Nodes



- Bean-shaped bodies distributed along various lymphatic vessels
- Fxn:
 - Filter lymph that enters & exits thru the lymphatic vessels
 - Connected to each other

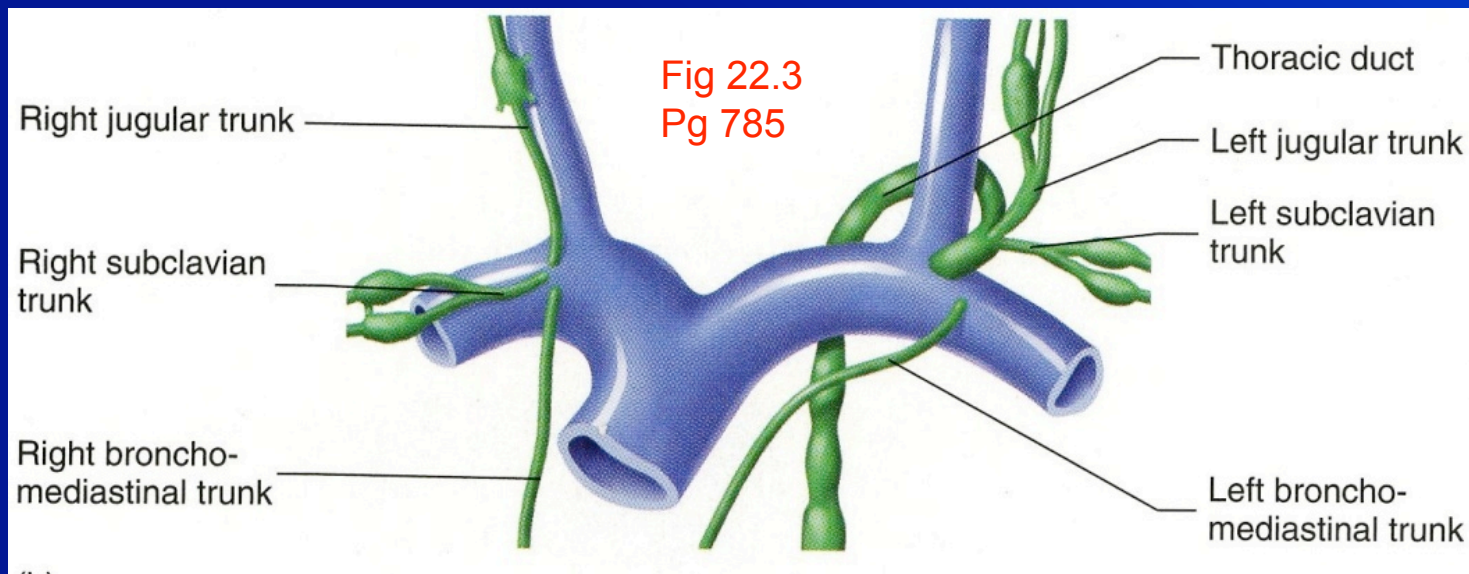


Major lymphatic trunks & areas drained



I. Lymphatic System

- Lymphatic trucks either directly drain into large veins or join to larger vessels called lymphatic ducts. Anatomy is quite variable.
 - Thoracic Duct:
 - Largest lymphatic vessel that drains right side of the body inferior to the thorax & the entire left side of the body
- Junctions usually occur @ internal jugular/subclavian jxn but can be on subclavian, jugular, or brachiocephalic



Lymphatic organs: qualify by having *lymphatic tissue*

Make-up of lymphatic tissue

Cells

Macrophages

Dendritic cells

Lymphocytes

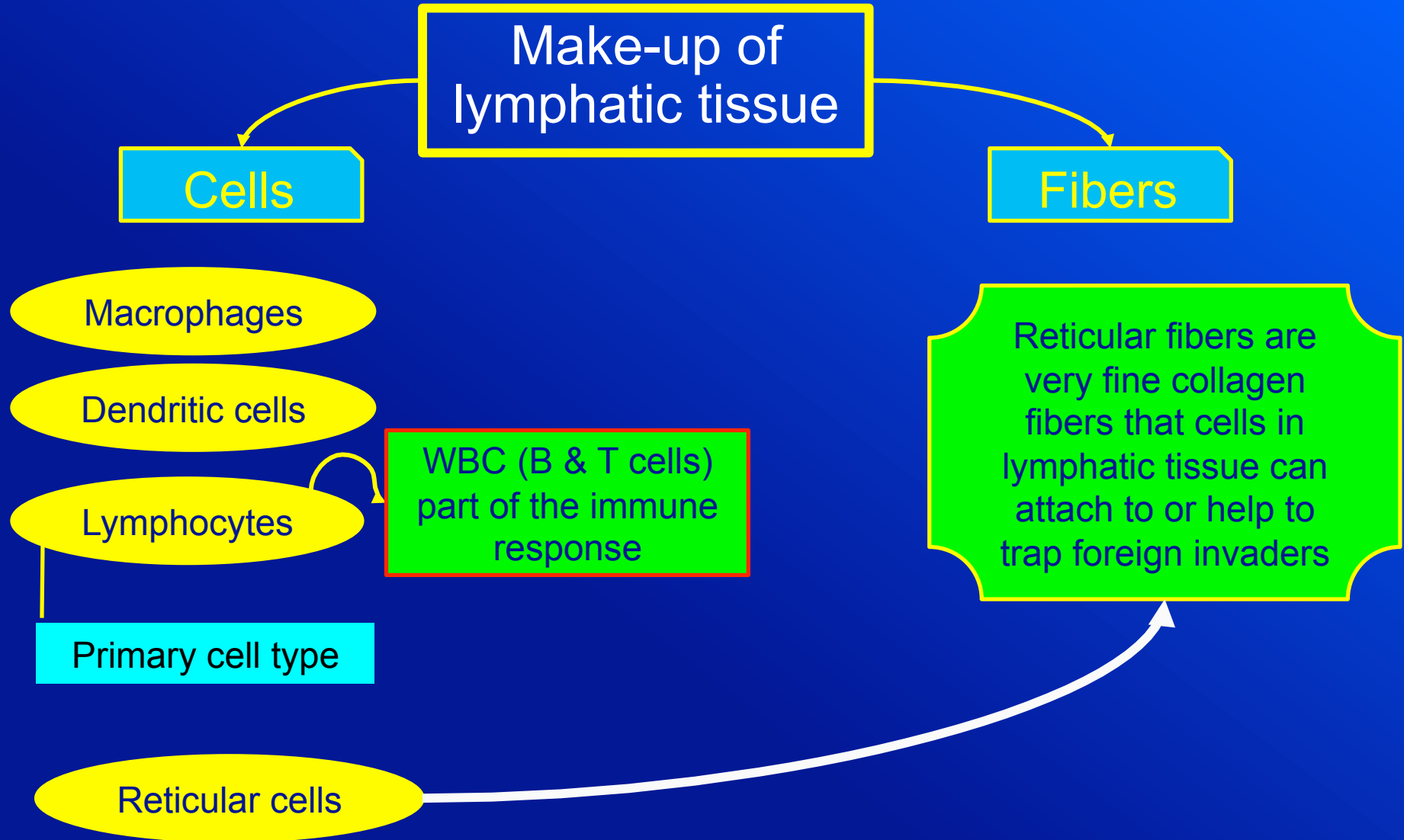
Primary cell type

Reticular cells

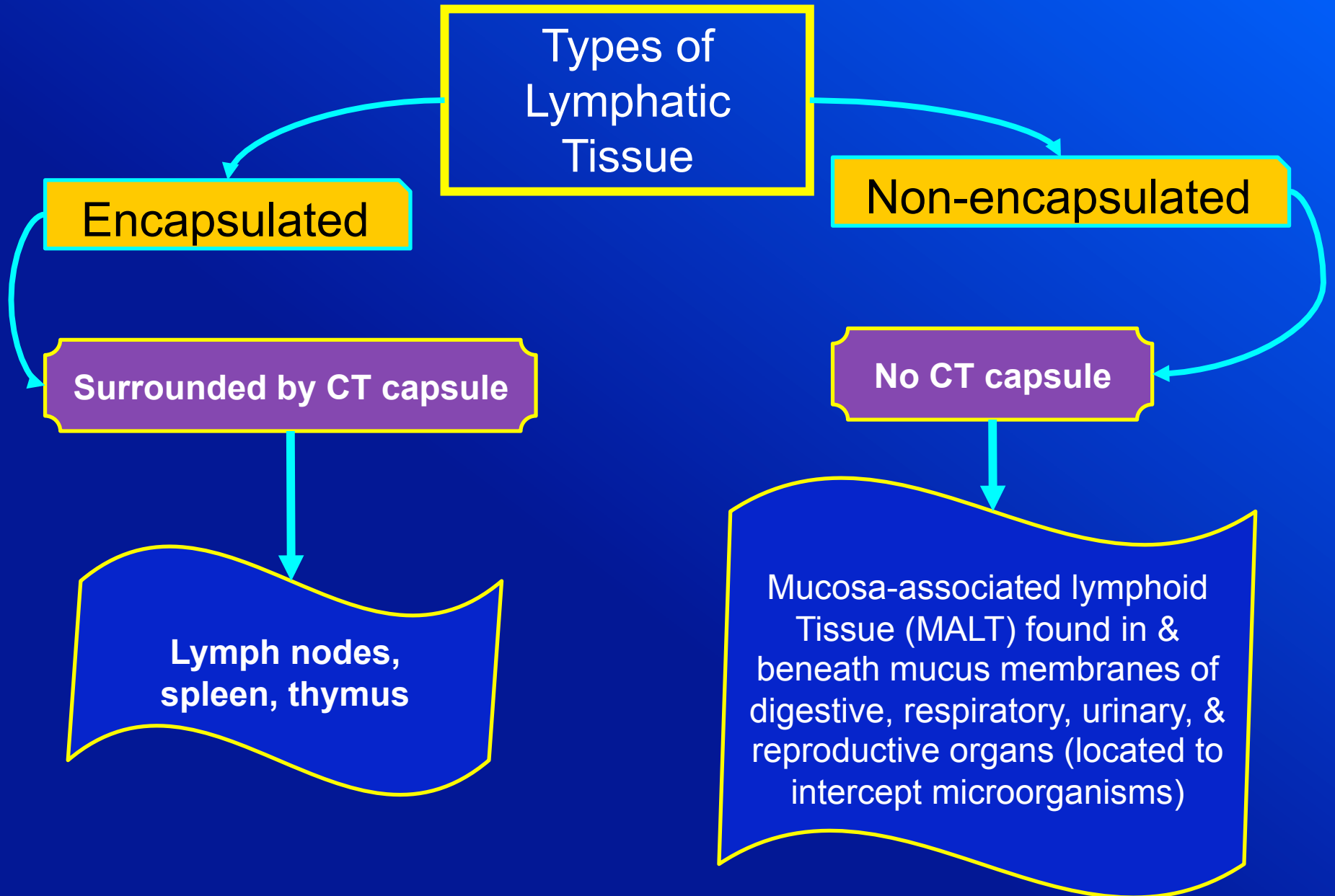
WBC (B & T cells)
part of the immune
response

Fibers

Reticular fibers are very fine collagen fibers that cells in lymphatic tissue can attach to or help to trap foreign invaders



Lymphatic organs: qualify by having lymphatic tissue



Lymphatic organs: qualify by having lymphatic tissue

Cell organization

Diffuse lymphatic tissue

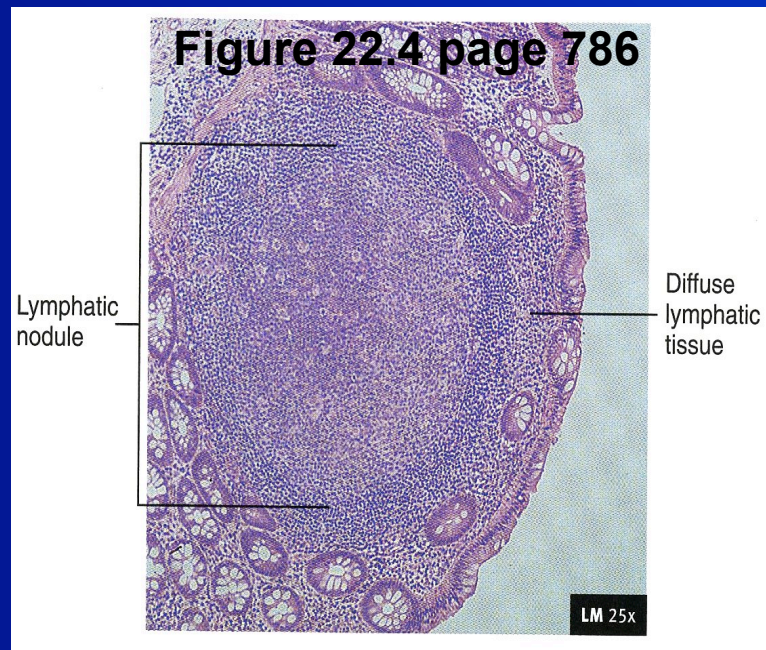
Dispersed lymphocytes, macrophages & other cells with no clear boundary. Blends with surrounding tissues

Deep in mucous membranes, around lymphatic nodules, & w/in lymph nodes & spleen

Lymphatic nodules

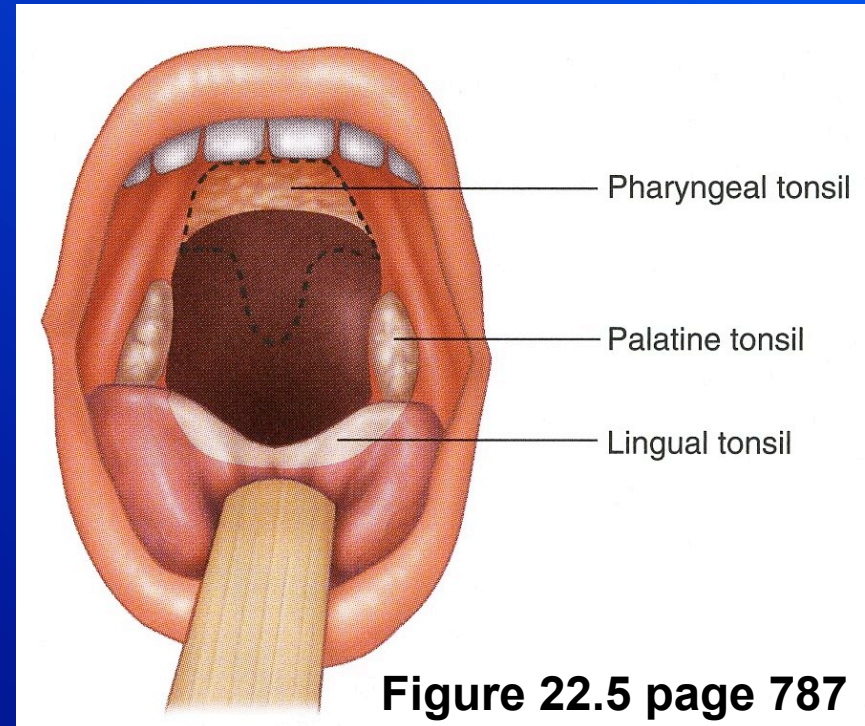
Denser arrangement of lymphoid tissue into somewhat spherical structures

Peyer's patches in the distal half of the small intestine, LCT of digestive, respiratory, urinary, & reproductive systems



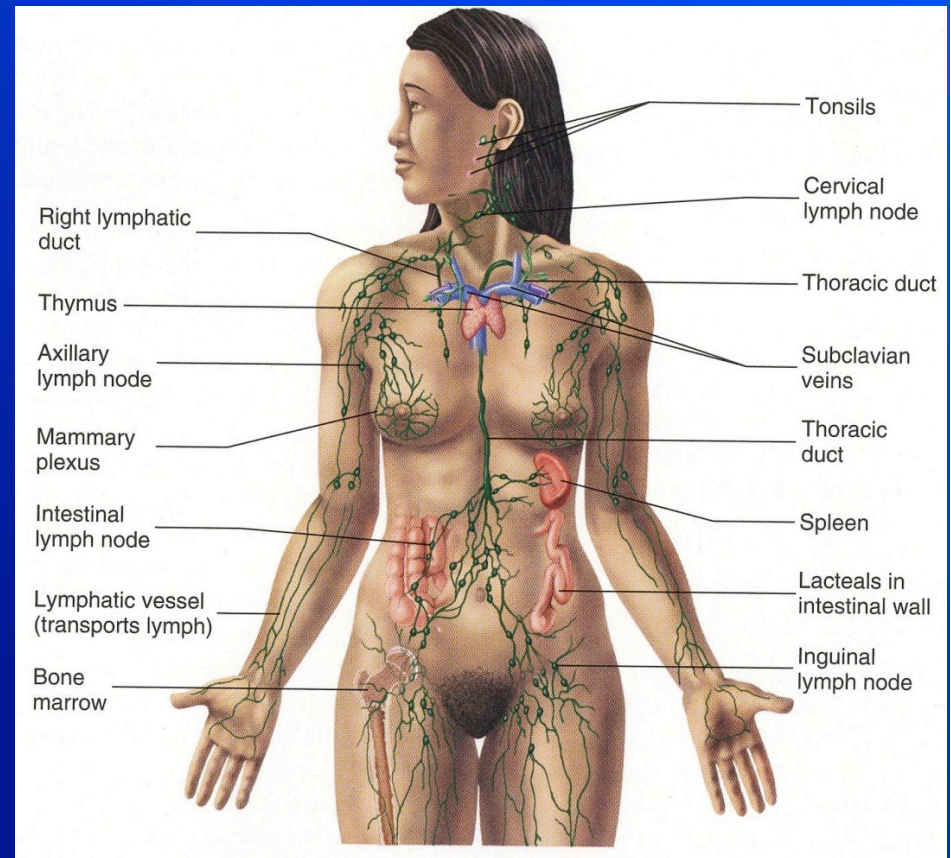
Lymphatic Organs: Tonsils

- Large groups of lymphatic nodules & diffuse lymphatic tissue deep in the mucus membranes of the oral cavity & nasopharynx.
- Protect against bacteria & other potentially harmful material entering the pharynx from the nasal or oral cavities
- 3 sets



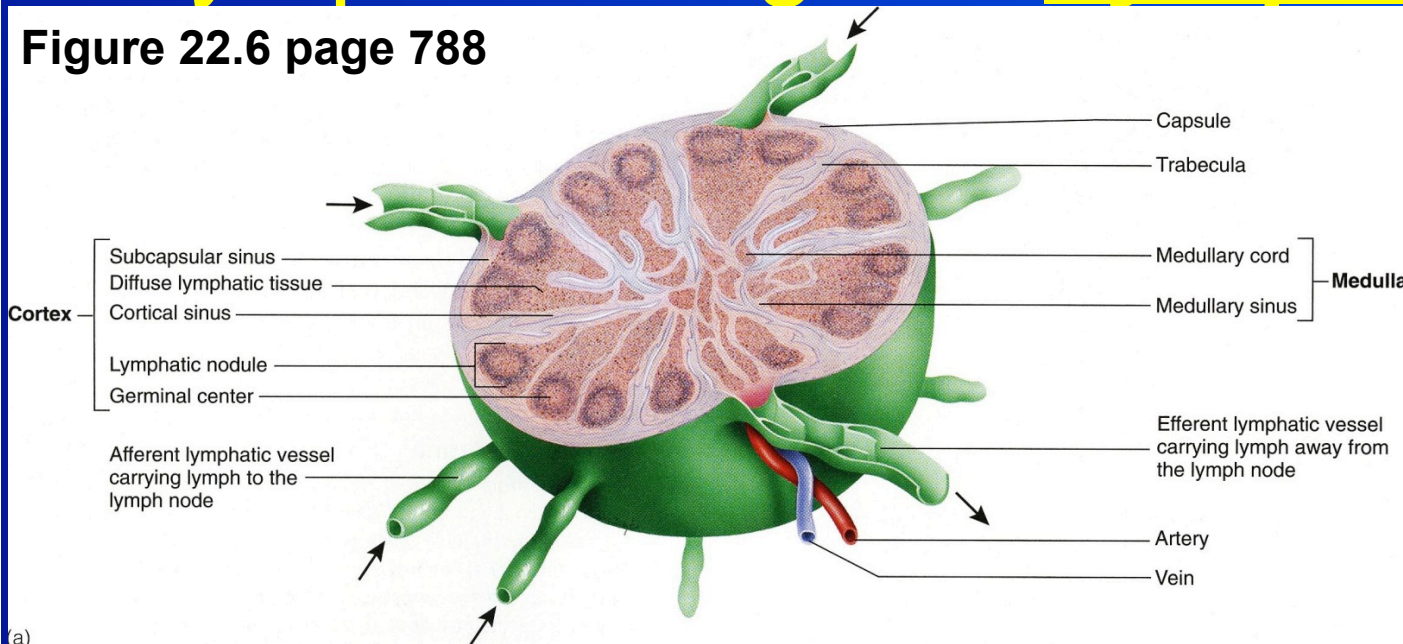
Lymphatic Organs: Lymph nodes (LN)

- Bean-shaped structures distributed along lymphatic vessels that filter lymph
 - Lymphocytes congregate, fxn, & proliferate w/in them
 - 2 types:
 - a) Superficial- found in the hypodermis
 - b) Deep- found everywhere else



Lymphatic Organs: Lymph Nodes

Figure 22.6 page 788

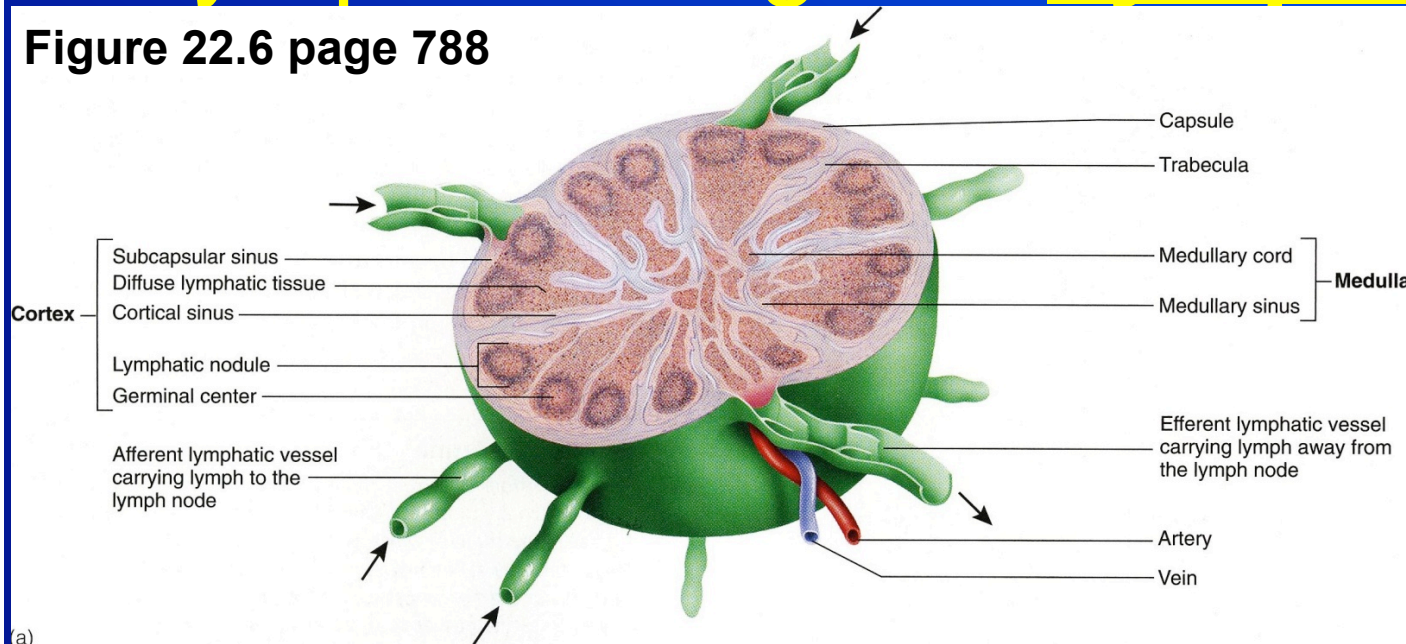


- Capsule
- Trabeculae
- Sinuses
- Cortex
- Medulla
- Medullary cords
- Afferent Lymphatic Vessels
- Efferent Lymphatic Vessels
- Germinal Center

- Capsule: DCT covering that surrounds each LN
- Trabeculae: extensions of the capsule into the LN that form a delicate internal skeleton.
- ❖ Reticular fibers extend from both the capsule & the trabeculae that form a network thru the LN.

Lymphatic Organs: Lymph Nodes

Figure 22.6 page 788

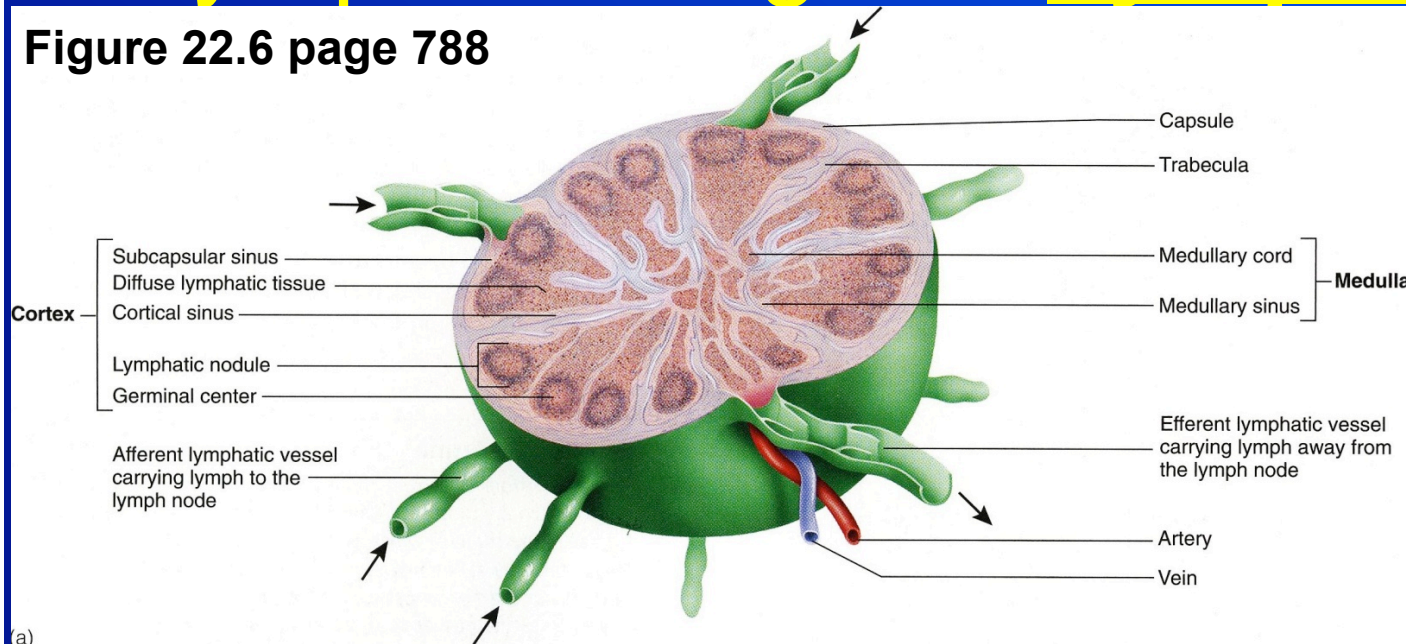


- Capsule
- Trabeculae
- Sinuses
- Cortex
- Medulla
- Medullary cords
- Afferent Lymphatic Vessels
- Efferent Lymphatic Vessels
- Germinal Center

- Lymphatic Tissue of the LN: lymphocytes & macrophages packed around reticular fibers
- Sinuses: areas in the LN w/o cells where reticular fibers extend over open spaces

Lymphatic Organs: Lymph Nodes

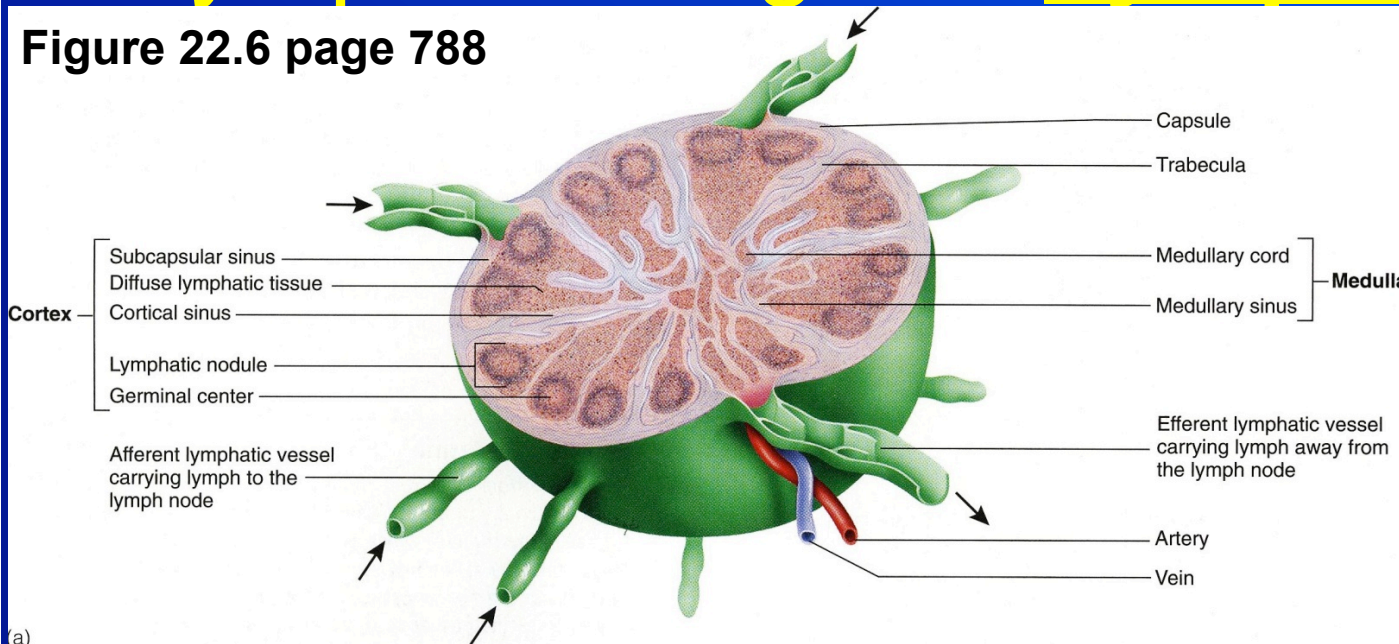
Figure 22.6 page 788



- **Capsule**
 - **Trabeculae**
 - **Sinuses**
 - **Cortex**
 - **Medulla**
 - Medullary cords
 - **Afferent Lymphatic Vessels**
 - **Efferent Lymphatic Vessels**
 - **Germinal Center**
- **Cortex:**
 - Made up of:
 - Subcapsular sinus
 - Cortical sinuses (separated by diffuse lymphatic tissue)
 - Trabeculae
 - Lymphatic Nodules
 - **Medulla**
 - Medullary sinuses
 - Medullary cords:
 - Branching, irregular strands of diffuse lymphatic tissue

Lymphatic Organs: Lymph Nodes

Figure 22.6 page 788



- Capsule
- Trabeculae
- Sinuses
- Cortex
- Medulla
- Medullary cords
- Afferent Lymphatic Vessels
- Efferent Lymphatic Vessels
- Germinal Center

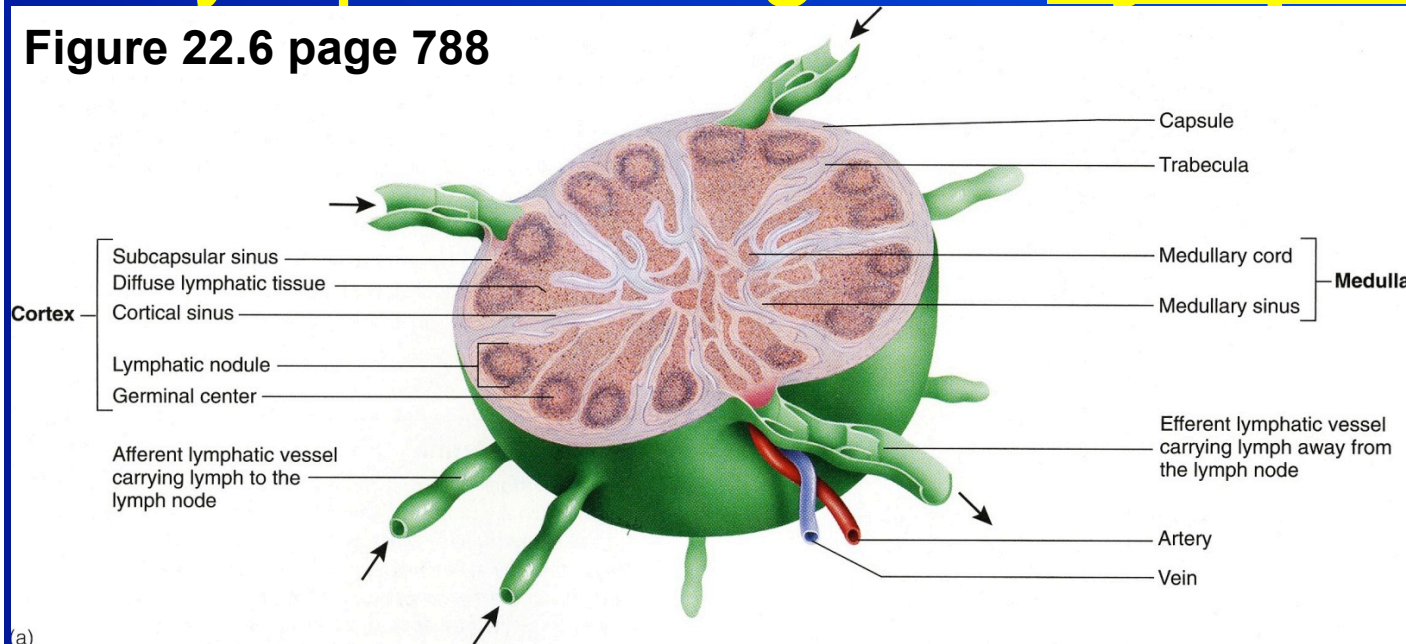
- Afferent lymphatic vessels: (ALV)
 - Carry lymph to the LN to be filtered
- Efferent lymphatic vessels: (ELV)
 - Carry filtered lymph away from LN

Path

Lymph → ALV → subcapsular sinus → filters thru cortex & medulla → Exit ELV

Lymphatic Organs: Lymph Nodes

Figure 22.6 page 788



- As lymph slowly filters thru the sinuses the macrophages lining them remove bacteria & other foreign substances.
- These foreign substances can also stimulate lymphocyte proliferation. New cells are released into the lymph & eventually reach the blood
- Germinal Centers: areas of rapid lymphocyte division

- Capsule
- Trabeculae
- Sinuses
- Cortex
- Medulla
- Medullary cords
- Afferent Lymphatic Vessels
- Efferent Lymphatic Vessels
- Germinal Center

Lymphatic Organs: Spleen

- Located in the left superior side of the abdomen
- Fxn:
 - Destroys defective RBCs
 - Detects & responds to foreign substances in the blood
 - Acts as a blood reservoir

Parts:

- **Stroma** :

Framework of the organ

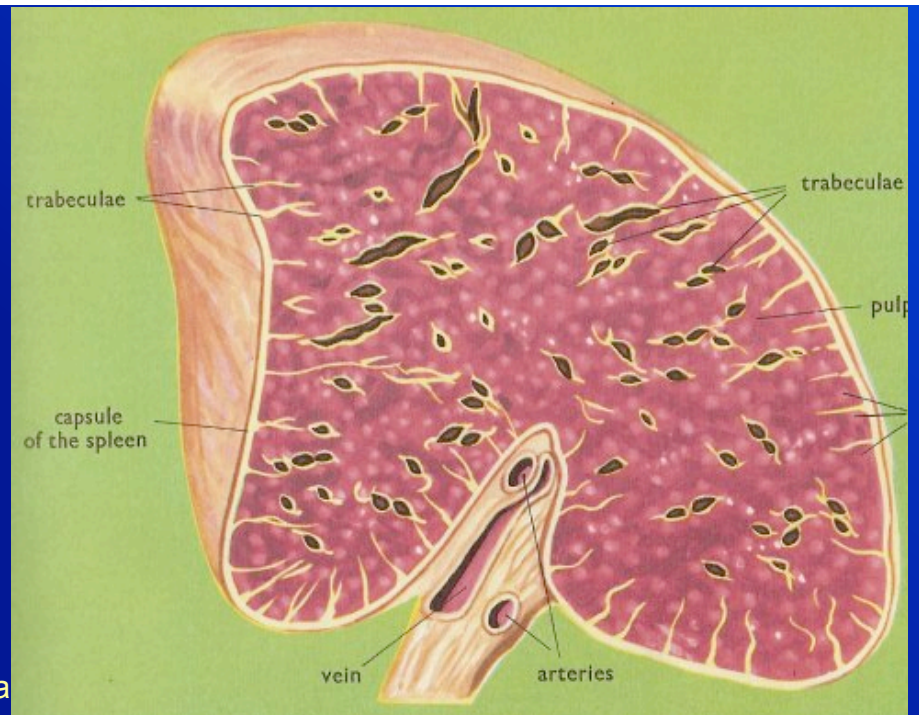
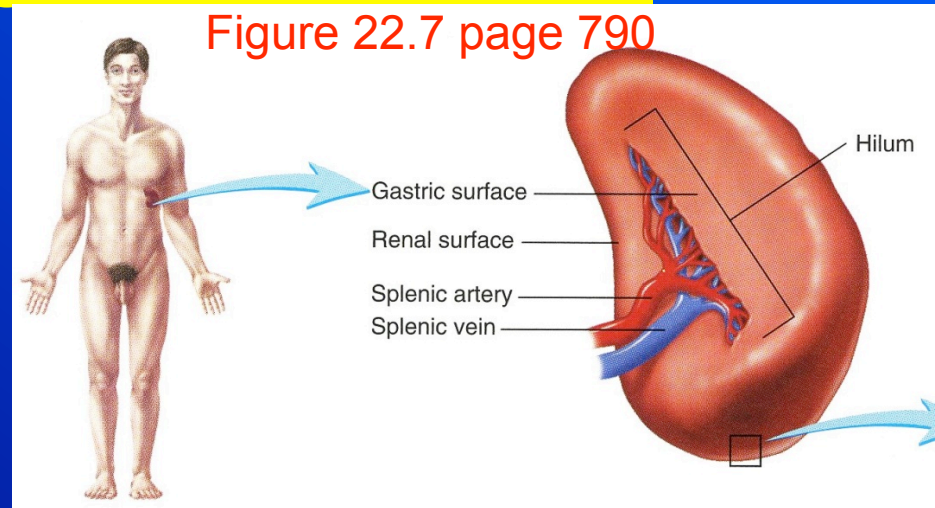
- Capsule
- Trabeculae
- Reticular fibers
- Fibroblasts

- **Parenchyma:**

Functional portions of the organ

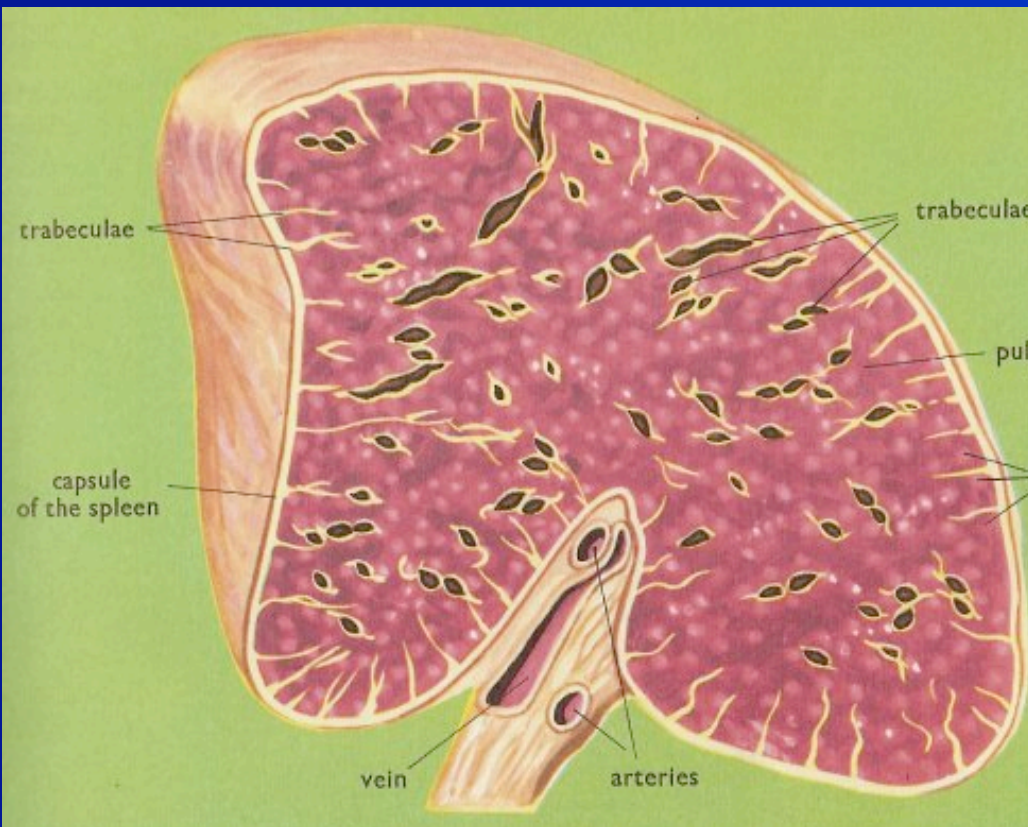
- White pulp
- Red Pulp

Figure 22.7 page 790



Lymphatic Organs: Spleen

Stroma

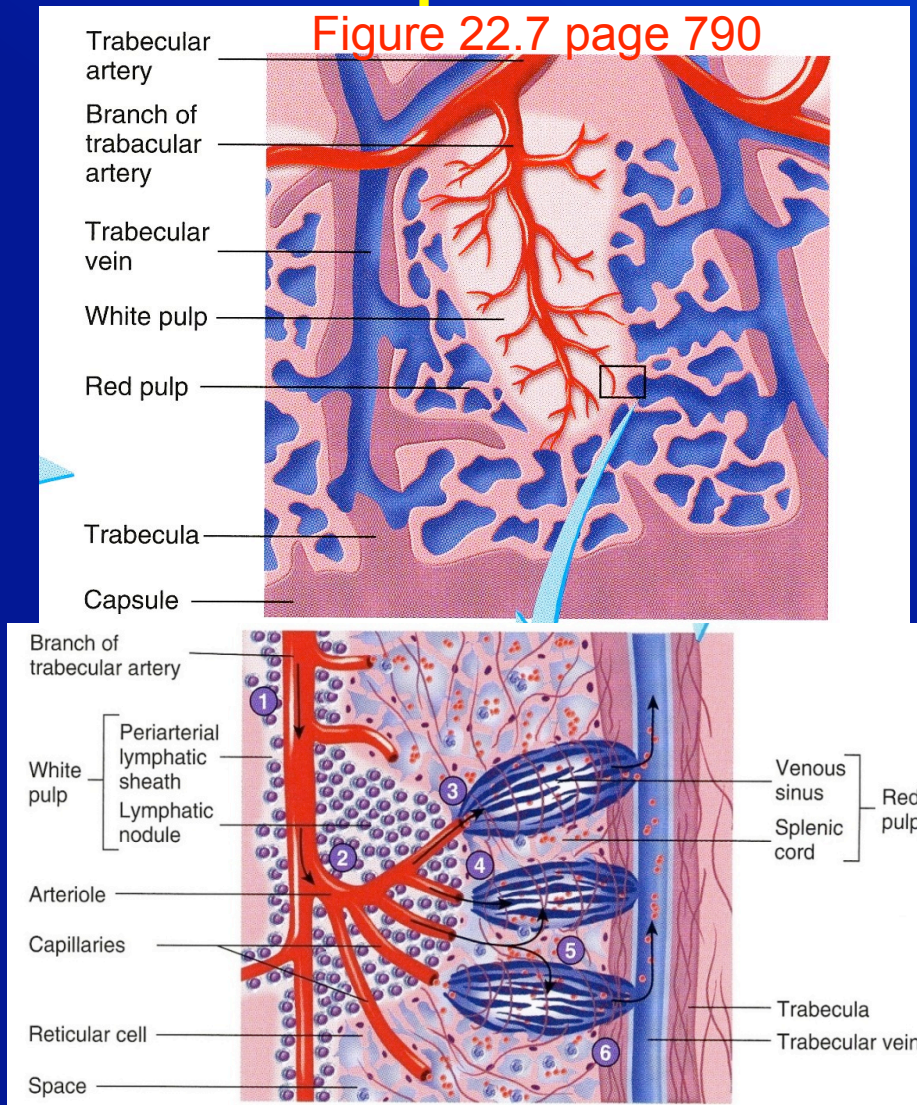


- Capsule: DICT covering w/a small amount of smooth muscle
- Trabeculae: bundles of CT fibers that extend from the capsule into the spleen dividing it into small interconnected compartments.
- Reticular Fibers: fine collagen fibers that aid in structure
- Fibroblasts: cells that make fibers

Lymphatic Organs: Spleen

Parenchyma

Figure 22.7 page 790



- White Pulp

- Lymphatic tissue (mostly lymphocytes & macrophages) arranged around arteries
- 1/4 of the volume of the spleen
- 2 major regions:
 - A. Periarterial lymphatic sheath
 - B. Lymphatic nodules

- Red Pulp

- Fibrous network filled w/ macrophages, RBCs, & enlarged capillaries that connect to veins
- 3/4 of the volume of the spleen
- 2 major regions:
 - A. Splenic Cords
 - B. Venous Sinuses

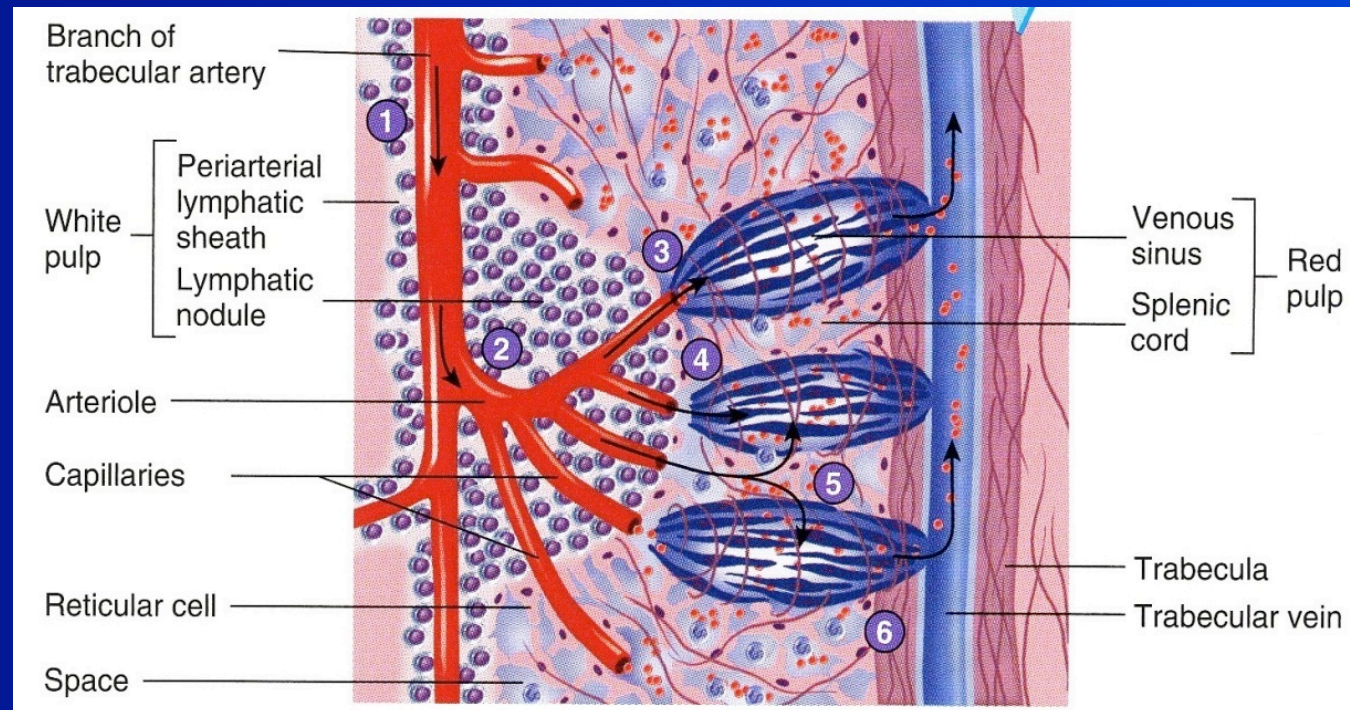
White Pulp

A. Periarterial lymphatic sheath

- Diffuse lymphatic tissue surrounding arteries & arterioles that extend into the lymphatic nodules
- ↑ T-cell []

B. Lymphatic nodules

- Dense collection of lymphatic tissues in a sphere.
- As the arteries enter they split & give rise to the capillaries supplying the red pulp
- ↑ B-cell []



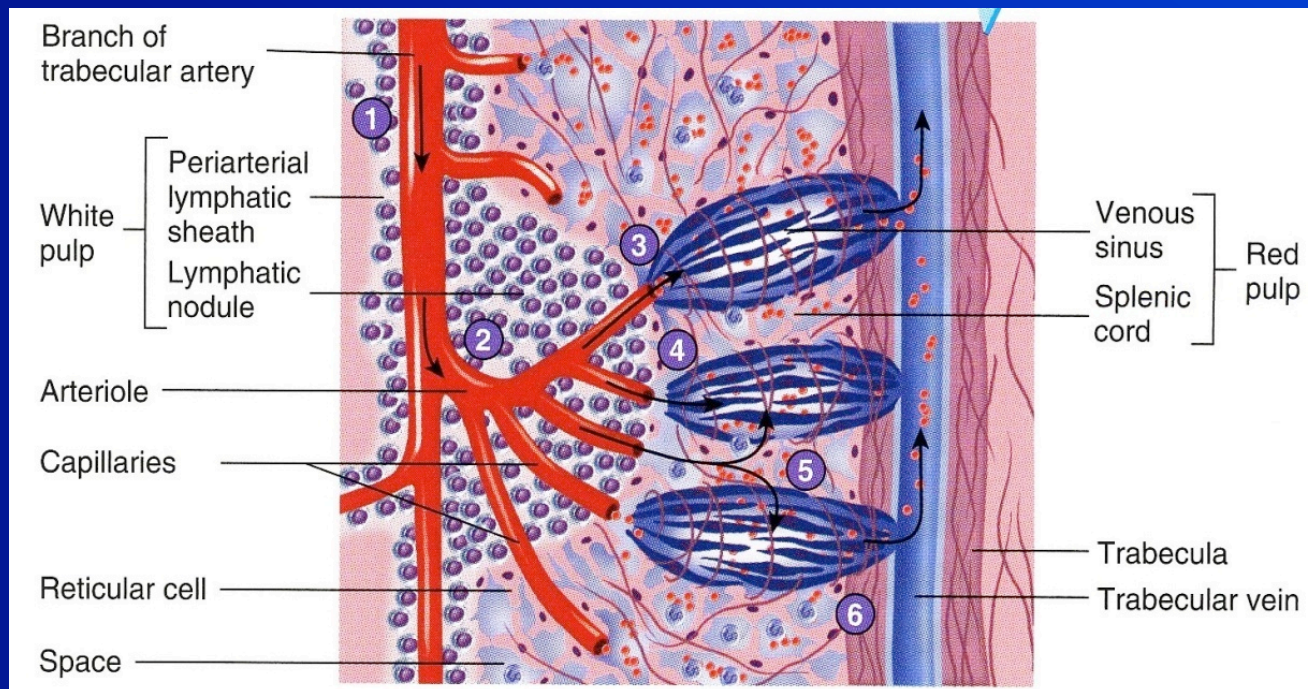
Red Pulp

A. Splenic Cord

- Network of reticular cells making reticular fibers. Between fibers there are splenic macrophages (fixed) & blood cells from the capillaries

B. Venous Sinus

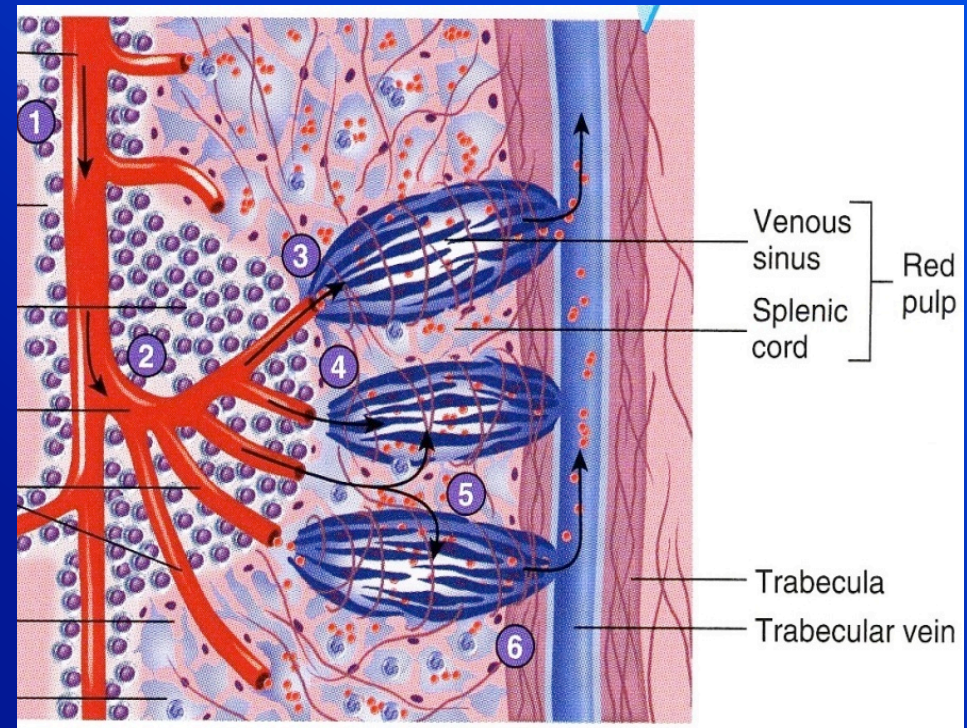
- Enlarged capillaries between the sections of splenic cords.
- Typically connect to trabecular veins which unite to form larger vessels that unite to form the splenic vein



Lymphatic Organs: Spleen

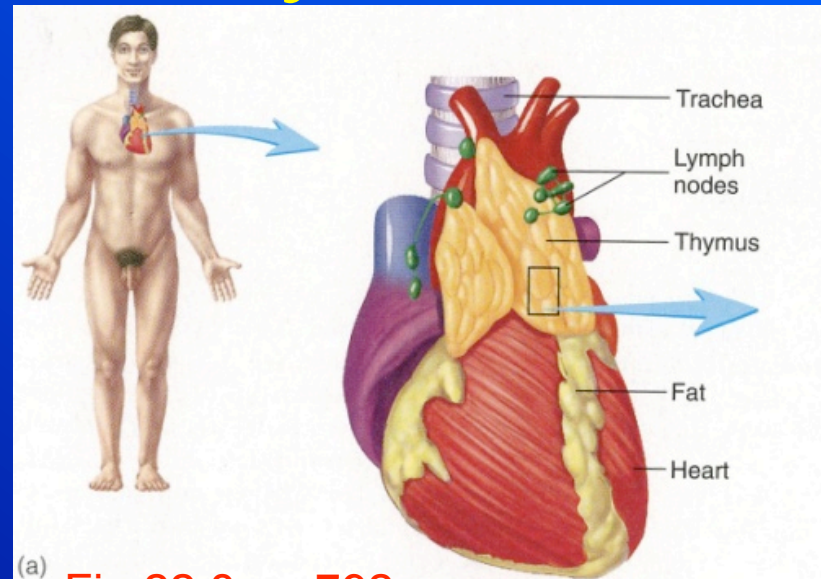
Blood flow through the spleen

- Rapid Flow
 - (3) capillaries with a direct link to the venous sinus move blood rapidly
- Slow Flow
 - Blood leaves the capillaries that have a gap between them & the venous sinus. The blood enters the venous cords must percolate thru the cells of the splenic cords then has to pass thru the walls of the venous sinus

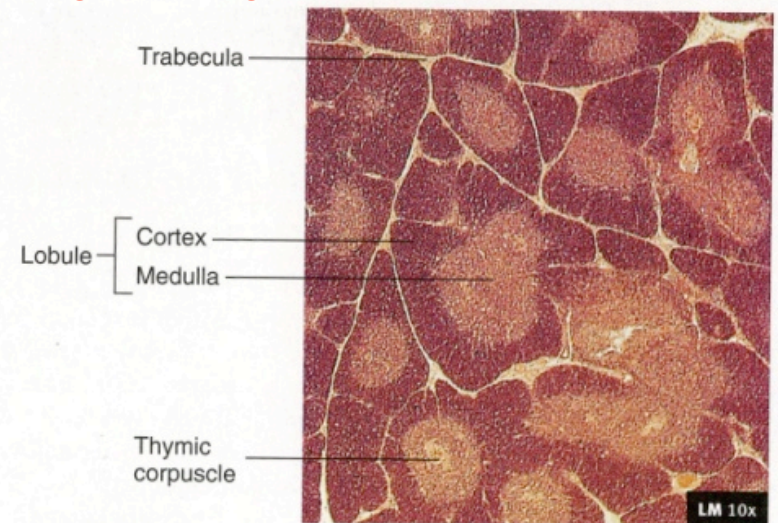


Lymphatic Organs: Thymus

- Bilobed gland in the superior mediastinum
- Site of T-cell maturation
 - Capable of reacting to foreign substances.
 - Most degenerate but those that survive migrate into the blood & travel
- Capsule: thin CT surrounding thymus
- Trabeculae: extend from the capsule into the organ dividing it into lobules.
- The lymphatic tissue framework consists of epithelial cells joined by desmosomes. These cells form compartments filled with lymphocytes.



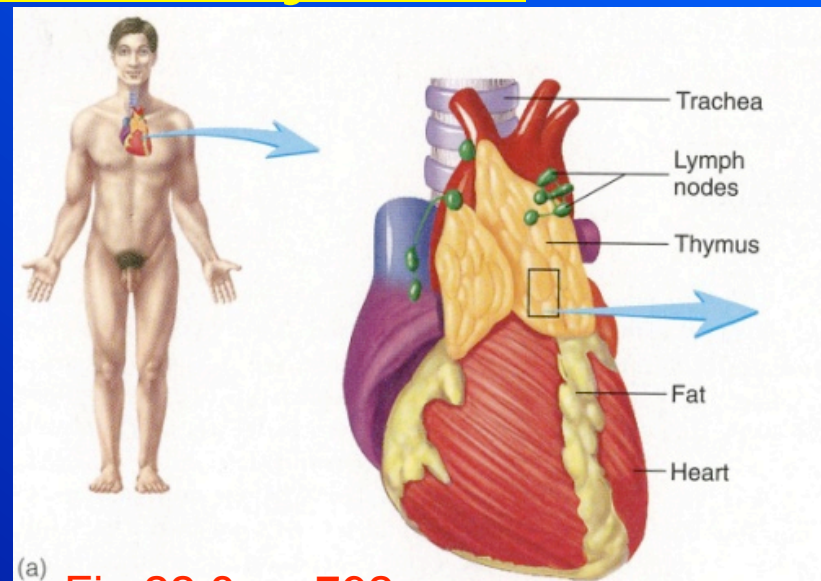
(a) Fig 22.8 pg 792



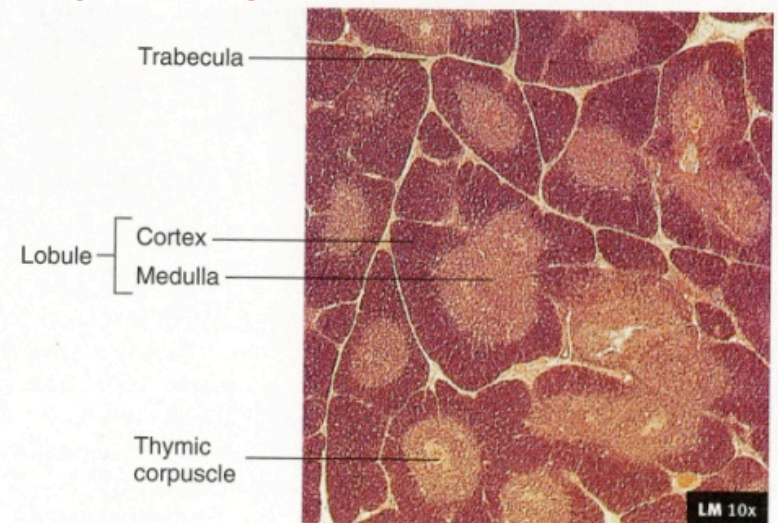
(b)

Lymphatic Organs: Thymus

- Lobules
 - Outer cortex
 - Lymphocytes are numerous & stain darkly
 - Inner Medulla
 - Few lymphocytes that stain lightly
 - Contain rounded epithelial structures called thymic corpuscles (unknown fxn)



(a) Fig 22.8 pg 792



(b)

Overview of the lymphatic system

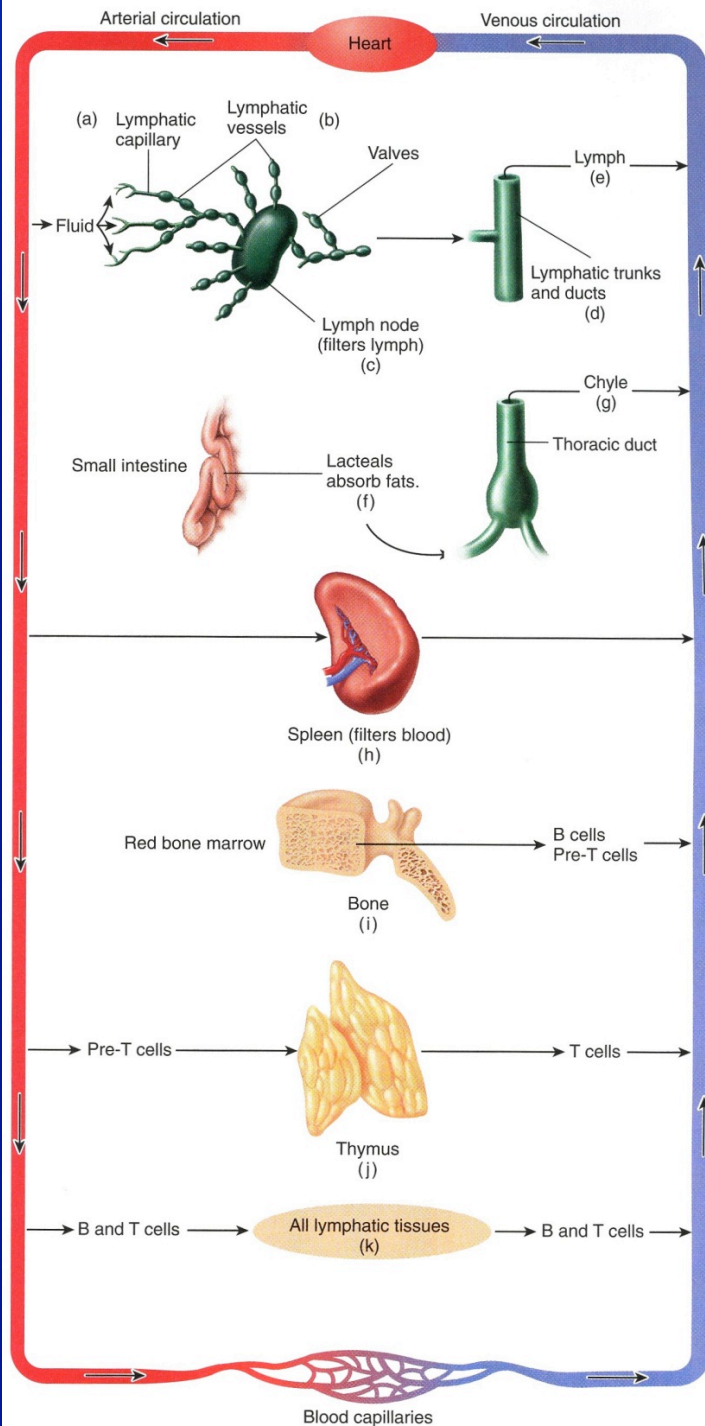


Figure 22.9 pg 793

- Lymphatic capillaries remove fluid from tissues. The fluid becomes lymph (see figure 22.2a).
- Lymph flows through lymphatic vessels, which have valves that prevent the backflow of lymph (see figure 22.2b).
- Lymph nodes filter lymph (see figure 22.6) and are sites where lymphocytes respond to infections, etc.
- Lymph enters lymphatic trunks and ducts (see figure 22.3b).
- Lymph enters the blood.
- Lacteals in the small intestine (see figure 24.16c) absorb fats, which enter the thoracic duct (see figure 22.3a).
- Chyle, which is lymph containing fats, enters the blood.
- The spleen (see figure 22.7) filters blood and is a site where lymphocytes respond to infections, etc.
- Lymphocytes (pre-B and pre-T cells) originate from stem cells in the red bone marrow (see figure 22.12). The pre-B cells become mature B cells in the red bone marrow and are released into the blood. The pre-T cells enter the blood and migrate to the thymus.
- The thymus (see figure 22.8) is where pre-T cells derived from red bone marrow increase in number and become mature T cells that are released into the blood (see figure 22.12).
- B and T cells from the blood enter and populate all lymphatic tissues. These lymphocytes can remain in the lymphatic tissues or pass through them and return to the blood. B and T cells can also respond to infections, etc., by dividing and increasing in number (see figures 22.18 and 22.22).

II. Immunity

The ability to resist the harmful FX
of microorganisms & other foreign
substances

II. Immunity

Innate Immunity

(Nonspecific resistance)

- Body recognizes & kills foreign invaders, using the same methods for every exposure
- No specificity or memory

Adaptive immunity

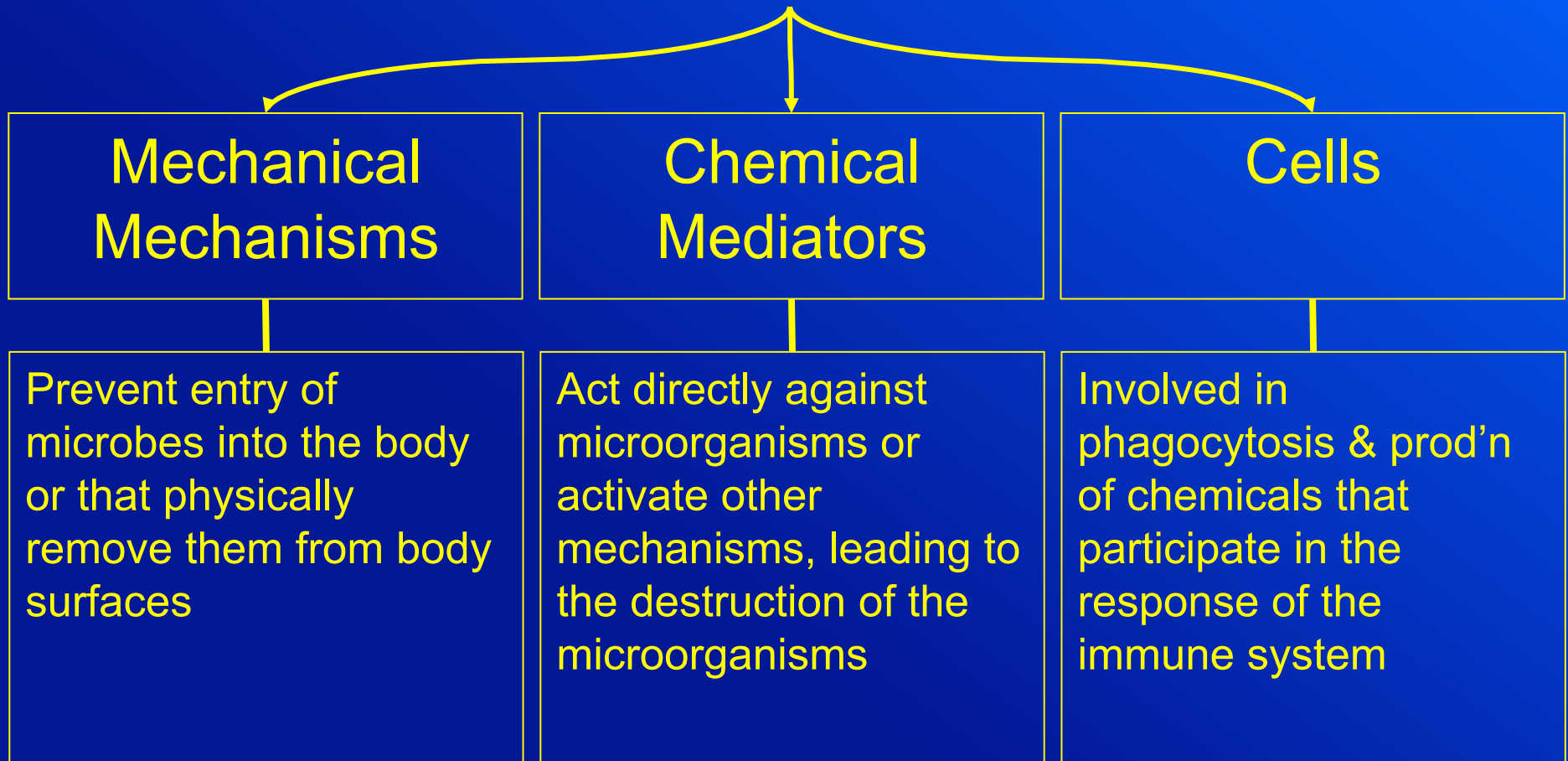
(Specific immunity)

- Body recognizes & kills foreign invaders, but the body's response improves with every exposure
- Specificity: ability to identify a particular substance
- Memory: the ability to “remember” a previously encountered foreign invader
 - Result: faster, stronger, longer response

III. Innate Immunity

- A. Mechanical Mechanisms
- B. Chemical Mediators
- C. Cells
- D. Inflammatory Response

3 main components of innate immunity



Mechanical Mechanisms

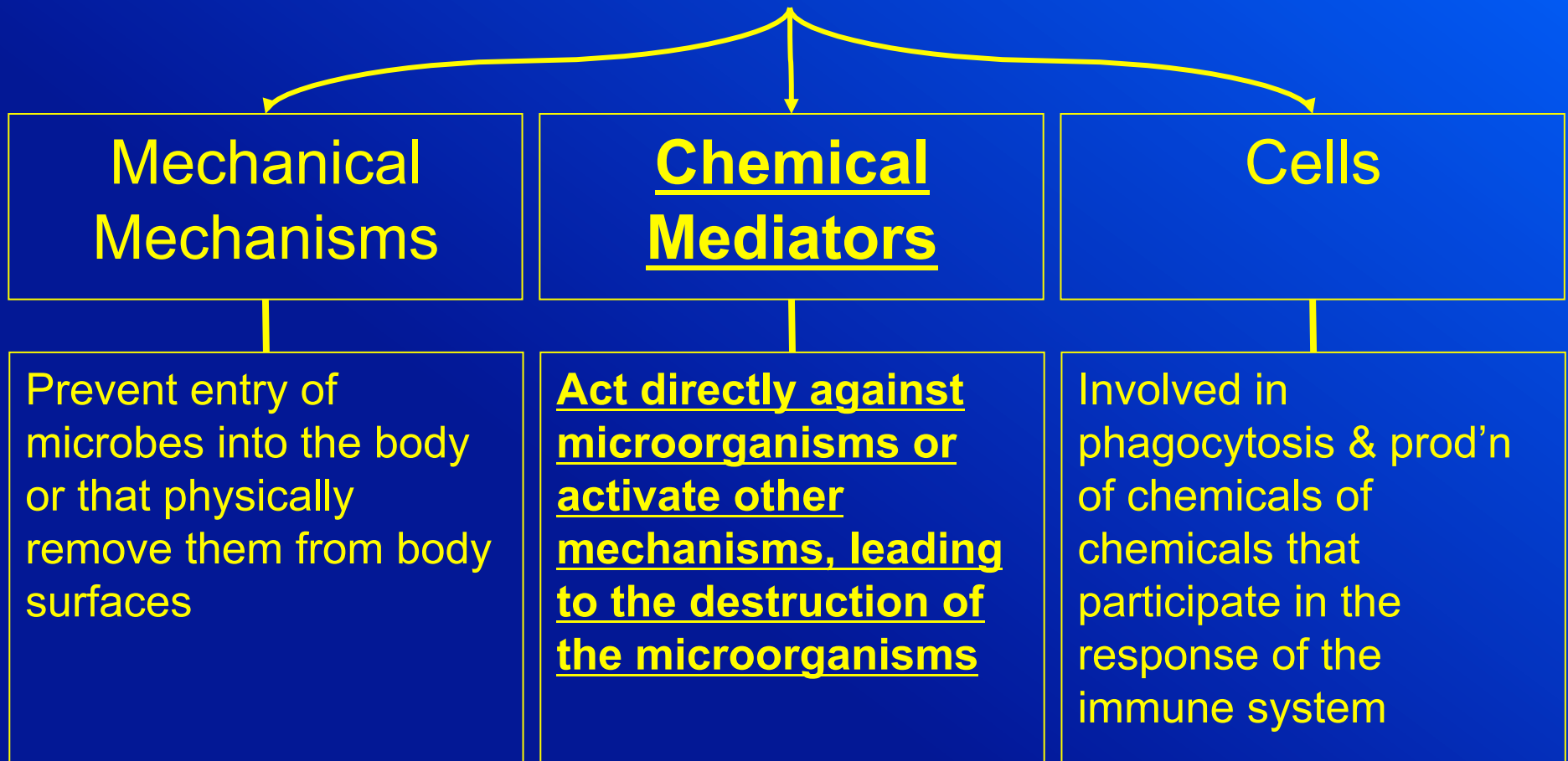
Prevent entry of microorganisms

- Skin forms a physical barrier preventing entry
- Mucus membrane's cilia sweep microbes trapped in mucus to back of throat where they can be swallowed

Remove Microorganisms

- Washed from the eye by tears.
- Washed from mouth by saliva
- Washed from urinary tract by urine

3 main components of innate immunity



Chemical Mediators

- Molecules responsible for many aspects of innate immunity
 - Cell Surface chemicals (lysozyme, sebum, & mucus)
 - Kill microorganisms
 - Prevent microorganism entry into the cell
 - Chemicals that cause tissue response (histamine, complement, eicosanoids)
 - Promote inflammation by causing vasodilatation, increase vascular permeability, attracting WBC's, & stimulate phagocytosis
 - Chemicals that bind to cell surface receptors & stimulate cell response (cytokines: (ex's) Interferons, interleukins, & lymphokines)
 - Secreted chemicals come from cell & bind to receptors on the neighboring cell or themselves
 - Regulate the intensity & duration of immune responses & stimulate the proliferation & differentiation of cells

Chemical Mediators: Surface Chemicals

Lysozyme

Tears, saliva, nasal secretions, sweat

Lyse Cells

Acid Secretion

Skin → Sebum
Stomach → HCl

Kill microorganisms
Prevent microorganism growth

Mucus

Mucus Membranes

Traps microorganisms until they can be destroyed

Chemical Mediators

Histamine

Released from mast cells, basophils, & platelets

- ❖ Causes vasodilation
- ❖ Increases vascular permeability
- ❖ Stimulates gland secretions (mucous, tears)
- ❖ Smooth muscle contraction in airway passage
- ❖ Attracts eosinophils

Kinins

Derived from plasma proteins in the blood

- ❖ Cause vasodilation
- ❖ Increases vascular permeability
- ❖ Stimulates pain receptors
- ❖ Attract Neutrophils

Interferons

Produced by most cells in the body

- ❖ Interfere with virus production
- ❖ Interfere with infection

Chemical Mediators

Complement

Plasma Protein

- ❖ Increase vascular permeability
- ❖ Stimulate histamine release
- ❖ Activate kinins
- ❖ Lyse Cells
- ❖ Promote Phagocytosis
- ❖ Attract
 - ❖ Neutrophils
 - ❖ Monocytes
 - ❖ Macrophages
 - ❖ Eosinophils

Prostaglandins

Prod'd in most cells in the body

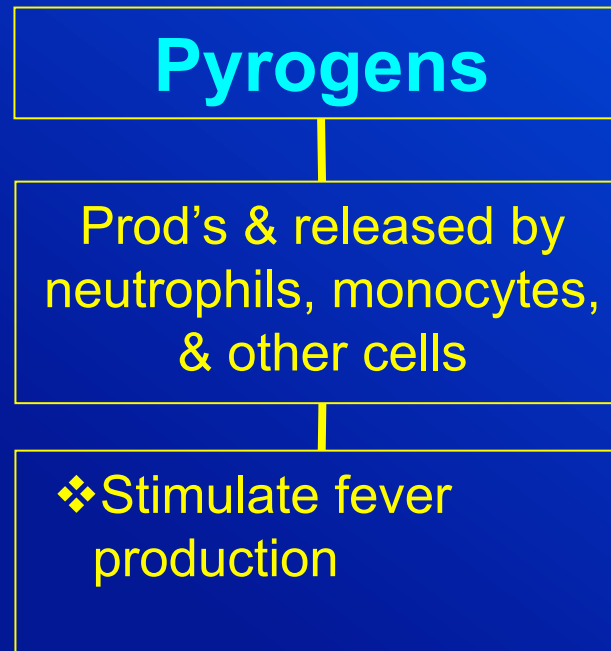
- ❖ Cause smooth muscle relaxation
- ❖ Cause smooth muscle vasodilation
- ❖ Increase vascular permeability
- ❖ Stimulate pain receptors

Leukotrienes

Primarily prod'd by Mast cells
Prod'd by basophils

- ❖ Cause prolonged smooth muscle contraction (esp lungs & bronchioles)
- ❖ Increase vascular permeability
- ❖ Attract:
 - ❖ Neutrophils
 - ❖ Eosinophils

Chemical Mediators



Chemical Mediators:

Chemicals that cause tissue response

Complement

Fxns:

- ❖ Increase vascular permeability
- ❖ Stimulate histamine release
- ❖ Activate kinins
- ❖ Promote Phagocytosis
- ❖ Attract
 - ❖ Neutrophils
 - ❖ Monocytes
 - ❖ Macrophages
 - ❖ Eosinophils
- ❖ Lyse Cells

- Group of 20 proteins that make-up 10% of serum globulin (C1-9, Factor B, Factor D, & Factor P)
- **Normal conditions:**
 - Circulate in blood in their non-fxnal form
- **Activation** occurs via a complement cascade: a series of rxns in wh/each component of the series activates the next

Complement

Alternative Pathway

- Part of non-specific/innate immunity
- C3 can combine with some foreign substances (part of bacteria or viruses)
- Once it becomes stabilized it activates the complement cascade

Classical Pathway

- Part of specific/adaptive immunity

Complement Pathways

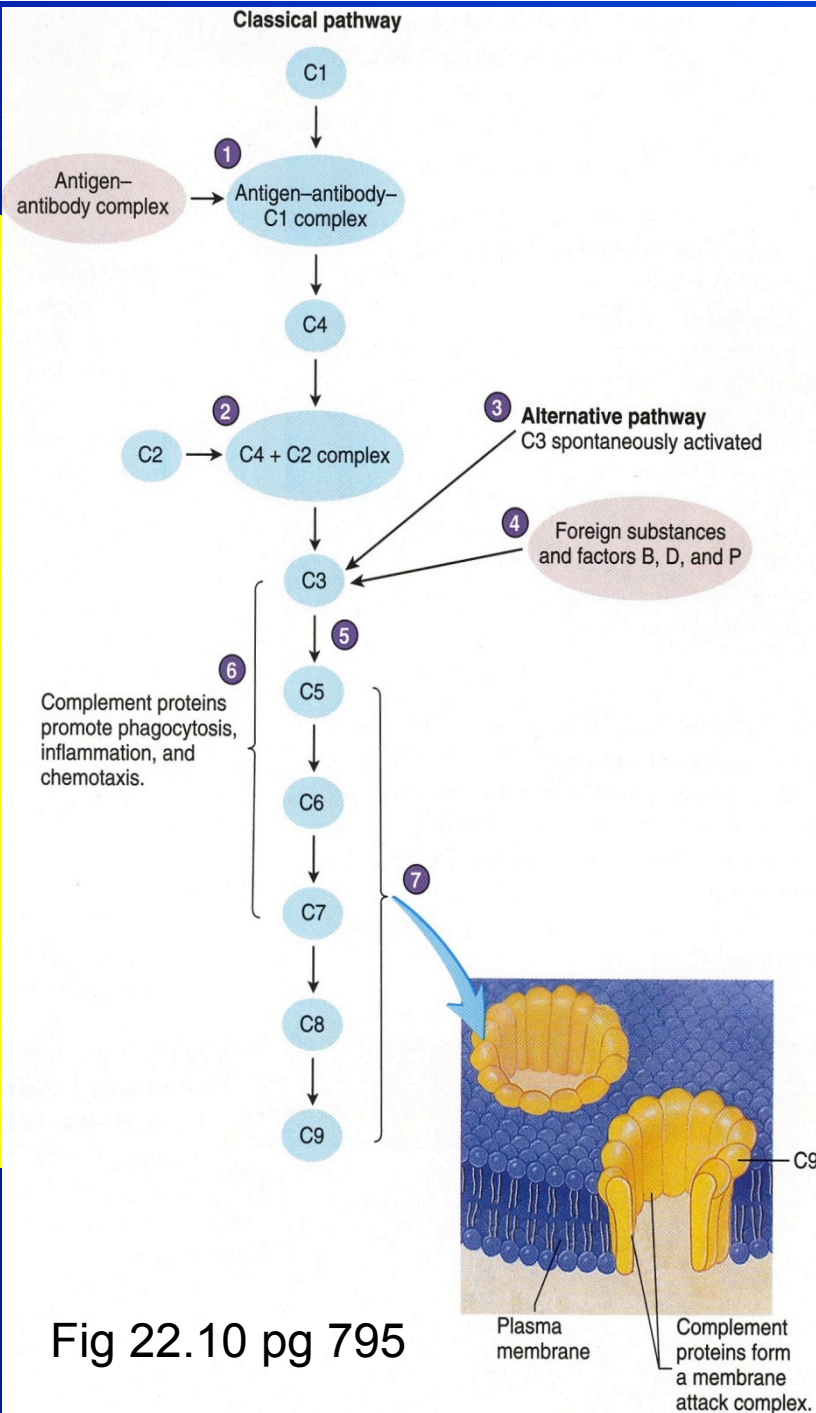


Fig 22.10 pg 795

Lysis by Complement

- Can form a **Membrane Attack Complex (MAC)**
- MAC's produce a channel thru the plasma membrane (PM)
 - Rxn begins when activated C3 attaches to the PM stimulating the "cascade".
 - Main component of MAC is C9 → they Δ shape, attach to each other, & form a channel thru the PM.
 - **The channel causes the influx of Na & H₂O which causes Cell Lysis
 - Cell Walls: MACs initially forms outside then lysozymes make a hole in the wall inducing cell lysis as the wall falls apart

Chemicals that bind to cell surface receptors & stimulate cell response

Interferons

Protect the body against viruses & perhaps some cancer

Can't directly attack the virus

Can't help itself



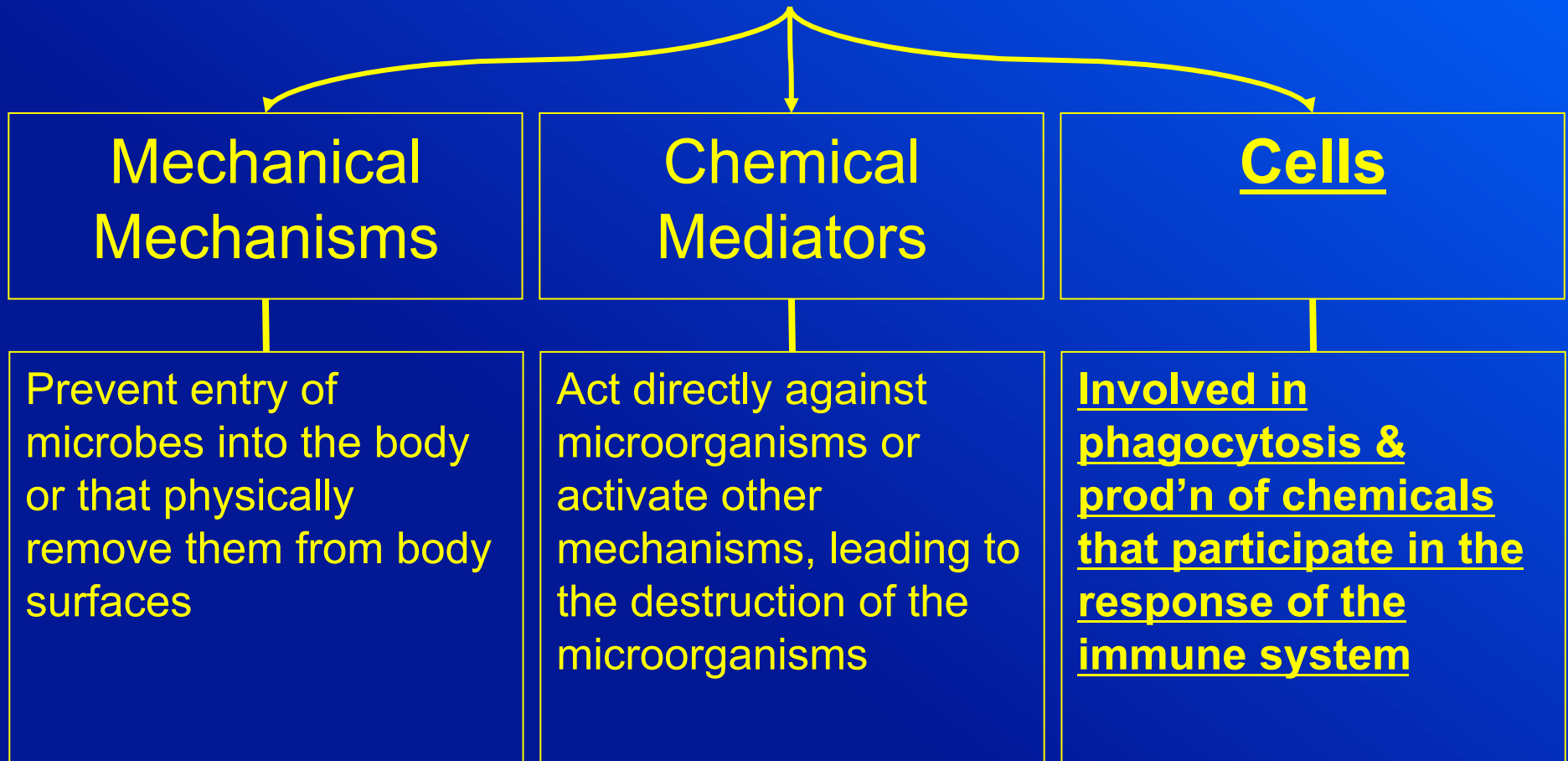
CAN produce & secrete Interferons



These cells no longer have to fear viral infection

Binds the cell surface stimulating the prod'n of antiviral proteins

3 main components of innate immunity



Cells involved in Innate immunity

- WBC's and the cells derived from them are the most important cellular components of the immune system
- These are prod'd in the bones marrow & some are finalized in the lymphatic tissue.
- To be effective they have to move into the tissues that need them,
- **Chemotactic Factors**: parts of microbes or chemicals released by tissue cells that act to attract WBC's in the process of **chemotaxis**
 - Compliment, leukotrienes, kinins, histamine

Cells of Innate/Nonspecific immunity

- A. Neutrophil (NP)
 - B. Monocyte/
Macrophage (M&M)
 - C. Basophil (BP)
 - D. Mast Cell (MSTC)
 - E. Eosinophil (EP)
 - F. Natural Killer Cell
(NKC)
- Inflammatory Response (IR)
 - Phagocyte (PC)
 - Microorganisms (MO)

Cells involved in Innate immunity

NP	M&M	BP
Derived from red bone marrow (RBM)	Derived from red bone marrow (RBM)	Derived from red bone marrow (RBM)
1 st cell to leave blood & enter infected tissue	Macrophages are derived from monocytes <i>Fixed or Wandering</i>	WBC's that leave the blood & enter infected tissue
PC's that die after 1 phagocytic event Release lysosomal enz's that kill microorganisms & damage tissue Act in chemotaxis releasing chemotactic factors to attract other cells to the area to & aid in IR	<ul style="list-style-type: none">- Long-lived phagocytes that eat more & larger material than NP's- Arrive late in infection & responsible for most of the clean-up at this stage<ul style="list-style-type: none">- Enhance IR via chemotaxis- "Fixed" → located at potential points of entry for MO	<ul style="list-style-type: none">- Can be activated by innate or adaptive immunity- Once activated they release other chemicals that 1) Prod IR or 2) Activate of other mechanisms (smooth muscle contraction)