Blood

It is the primary transport medium of the body.

Function of blood:

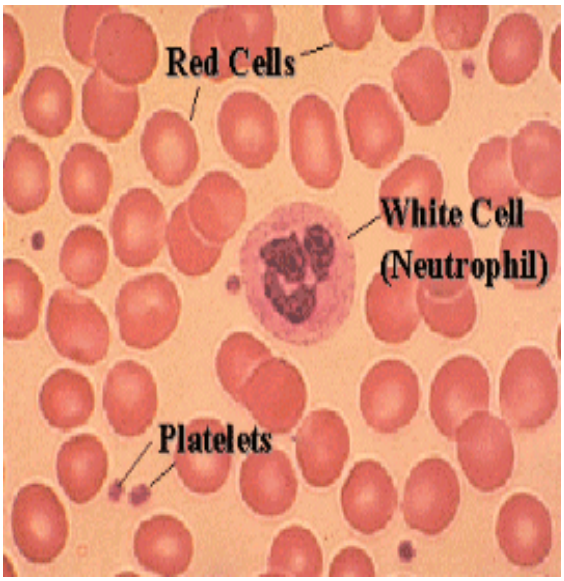
1- Transport of oxygen (O2),carbon dioxide(CO2), nutrients, waste products,& hormones.
2- Regulation of pH level, body temperature & H_2O content of cells.
3- Protection in form of clotting mechanisms & immune system components as antibodies, etc.

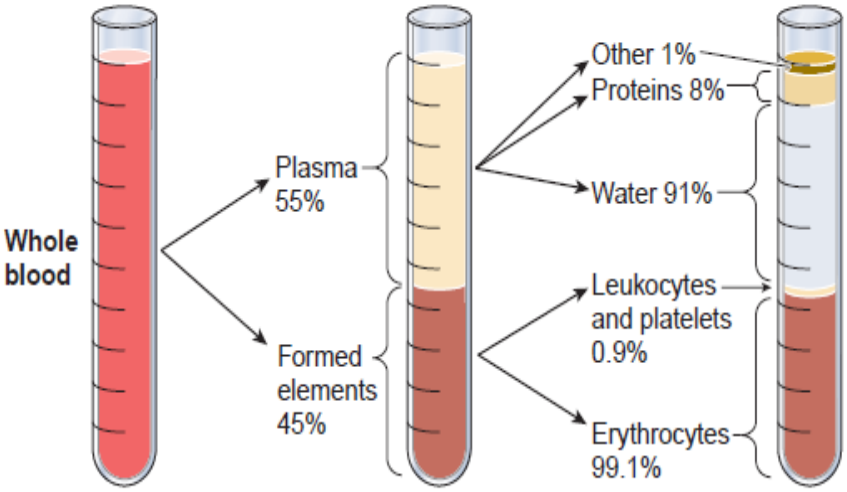
Components of Blood - average adult has about 5 liters:

1- Formed elements

   a- Red blood cells (erythrocytes) RBC.
   b- White Blood Cells (Leucocytes) WBC
   c- Platelets (Thrombocytes)

2- Plasma = water + Dissolved Solutes (**Plasma :** It is a pale yellow colloidal solution, which is a liquid containing suspended substance which are plasma proteins).





Composition of whole blood. Percentages show the relative proportions of the different components of plasma and formed elements.

Hematocrit
Blood is separated into plasma, erythrocytes (RBC), & a small amount of leukocytes (WBC) & platelets. Hematocrit measurement includes only erythrocytes.

Hemopoiesis

Production of all types of blood cells (formed elements) hemopoietic stem cells in bone marrow

General Properties of Whole Blood*	
Fraction of body weight	8%
Volume in the adult body	Female: 4–5 L; male: 5–6 L
Volume/body weight	80-85 mL/kg
Mean temperature	38° C (100.4° F)
pH	7.35–7.45
Viscosity (relative to water)	Whole blood: 4.5–5.5; plasma: 2.0
Osmolarity	280–296 mOsm/L
Mean salinity (mainly NaCl)	0.9%
Hematocrit (percent RBCs by volume)	Female: 37%–48%; male: 45%–52%
Hemoglobin	Female: 12–16 g/dL; male: 13–18 g/dL
Mean RBC count	Female: 4.8 million/ μL; male: 5.4 million/μL
Platelet count	130,000–360,000/μL
Total WBC count	5,000 - 10,000/μL

*Values may vary slightly depending on the testing methods used.

Plasma:

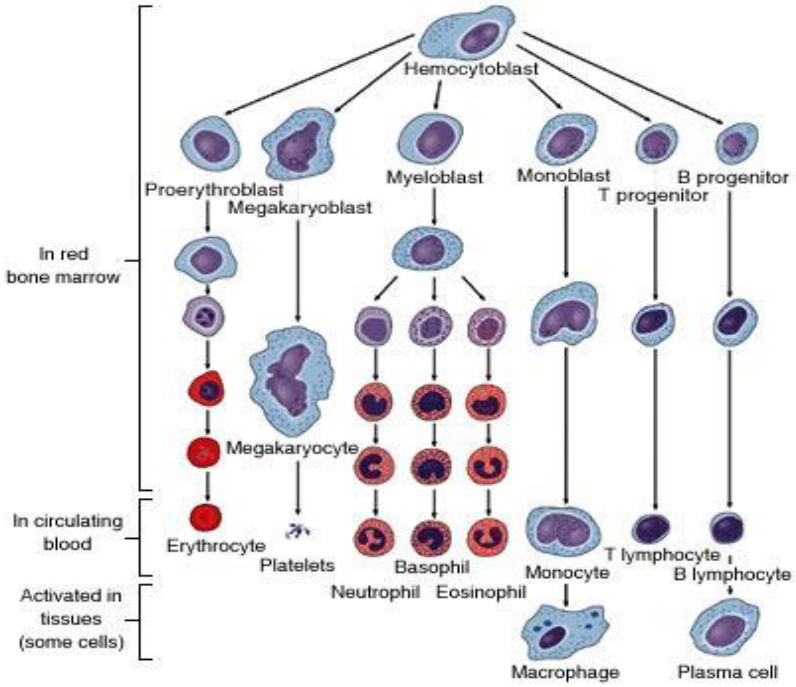
1 - Water - serves as transport medium; carries heat

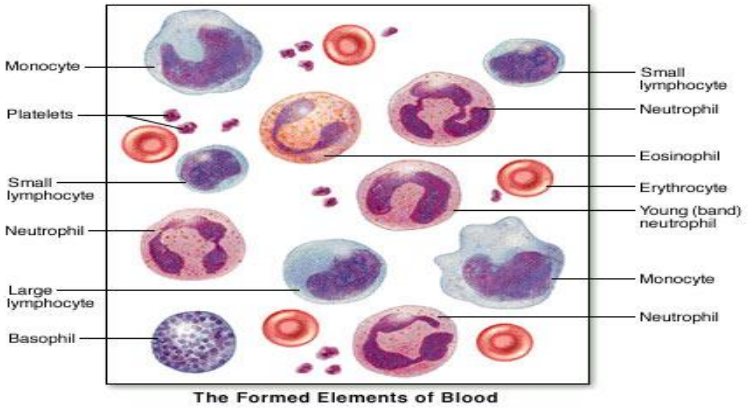
2 - Proteins

- Albumins
  - 60-80% of plasma proteins
  - most important in maintaining osmotic balance
  - produced by liver
- Globulins
  - gamma globulins are immunoglobulins (IgG, or antibodies) produced by lymphocytes
- Fibrinogen
  - important in clotting
  - produced by liver

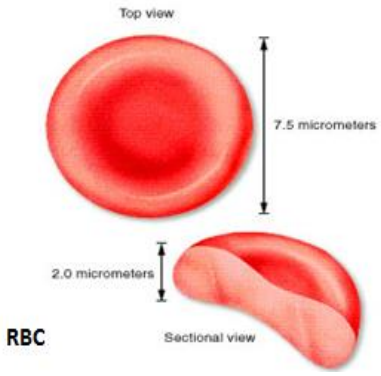
3 - Nutrients - glucose, amino acids, lipids & vitamins

4 - Waste products - e.g., nitrogenous wastes like urea





The Formed Elements of Blood



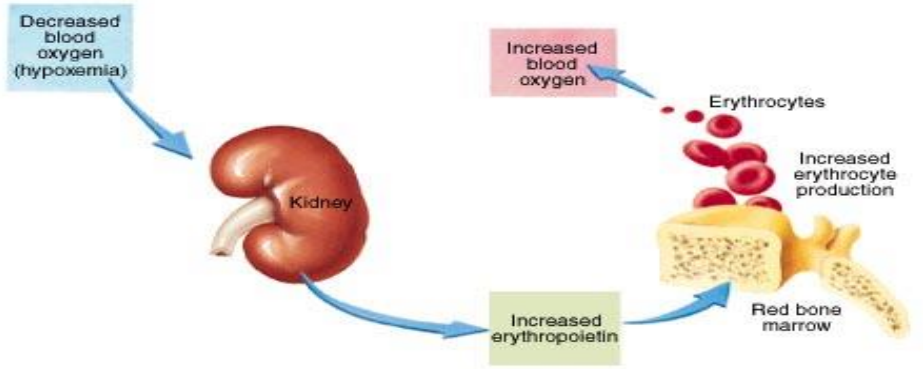
ERYTHROCYTE (Red blood cell - RBC)

- 95 % of the elements are RBC.
- **Shape**: biconcave disks with edges that are thicker than the center of the cell. This shape increases their surface area→ movement of gases into & out of erythrocyte more rapid. It can bend around its thin center, ↓ing its size & enabling it to pass easily through small vessel.
- lack a nucleus & cannot reproduce (average lifespan = about 120 days)
- Each cell contains 250 million molecule of hemoglobin (Hb), which is O2 & CO2 transporter.
- **Function**: is transportation of respiratory gases O_2 & CO_2.
- Contain carbonic anhydrase (critical for transport of carbon dioxide)

Erythrocyte Production (erythropoiesis)

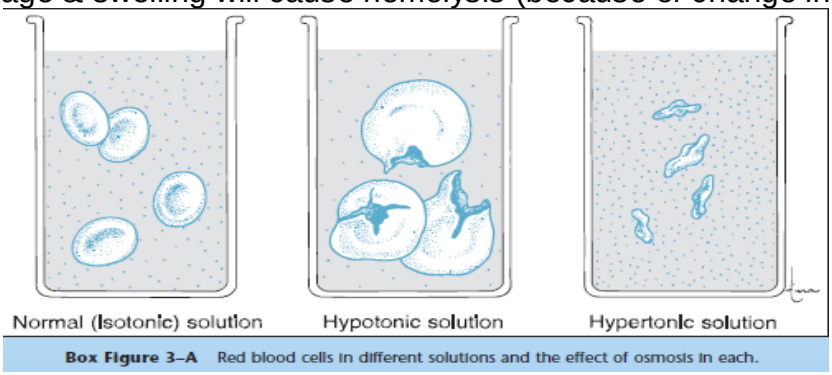
- Early few weeks of embryo nucleated RBCs are formed in yolk sac.
- Middle trimester mainly in liver & spleen & lymph nodes.
- Last month's RBCs are formed in bone marrow of all bones
- in adults, erythropoiesis occurs mainly in the marrow of the sternum, ribs, vertebral processes, and skull bones.
- Shaft of long bone stop to produce RBC at puberty while epiphysis continued

- **rate is regulated by oxygen levels**: hypoxia is detected by cells in the kidney→kidney cells release **erythropoietin** H into the blood → erythropoietin stimulates erythropoiesis by the bone marrow.



RBC fragility: RBC is a fragile cell & its shape is maintained by osmotic equilibrium.

- RBC + hypertonic solution →RBC shrink (fluid moves out)
- RBC + hypotonic solution → swelling occurs (fluid moves in).
- Both cases, shrinkage & swelling will cause hemolysis (because of change in shape.



Box Figure 3–A Red blood cells in different solutions and the effect of osmosis in each.

Hemoglobin (Hb):

- Each Hb molecule consists of 4 polypeptide globin chains (2 α & 2 β). Each chain is conjugated with a heme group that has an iron(ferrous Fe^{+2}) at its center. It is the iron to which O_2 binds.

➢ Normal adult Hb is composed of:

1- HbA = α 2 β 2
2- HbA_2 (2.5%) is composed of 2 α & 2 delta chains.
3- Glycosylated Hb, Hb attached to glucose in terminal portion of β chains.

➢ Normal fetal Hb (HbF):

- It Is similar to HbA, but β chains are replaced by gamma chains.
- It is replaced by HbA after birth, but in some people, it may persist in low concentrations.
- It binds to O2 more rapidly than HbA.

Reactions of Hb:

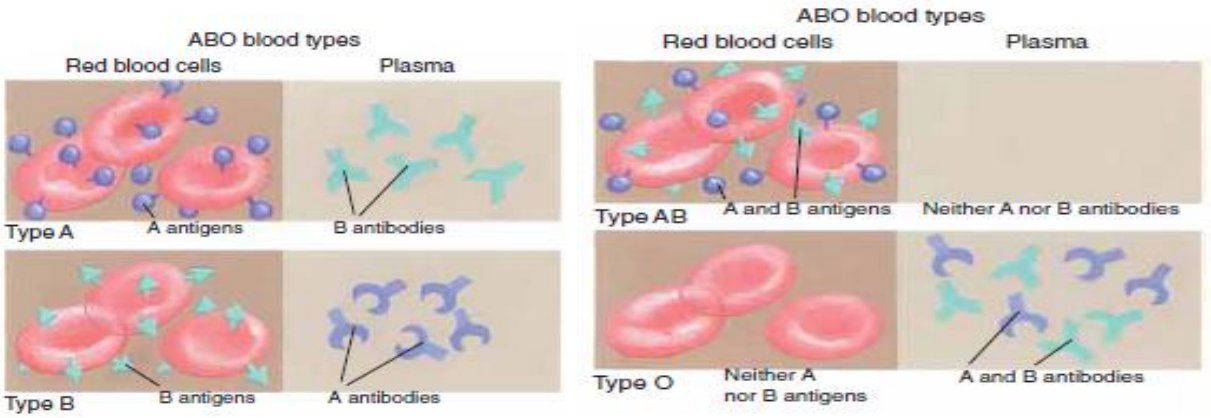
1- Hb + O2 → loosely ← HbO_2 (**oxyhemoglobin**). This reaction is called oxygenation (not oxidation), This reaction is affected by; pH; temperature; 2,3DPG (2,3 diphosphoglycerate); where H^+ & 2,3DPG compete with O2 for binding with Hb causing release of O2 to tissues.

2- Hb + CO → HbCO(**carboxyhemoglobin**). CO affinity to Hb is greater than O2 & is very stable.
3- **Oxidation** of Hb; by contact with certain drugs or agents ($KMnO_2$, $KClO_3$, O_3) causing ferrous to change into ferric state→ formation of methemoglobin (which is dark in color). If its % is:
10-25% → cyanosis; 35% → dyspnea; 70% → death.

Catabolism of Hb:

- Hb is released from damaged RBCs, & catabolized into globin & heme.
- Globin will be broken into amino acids in liver.
- Heme converted into →insoluble bilirubin → transported to liver to be conjugated with glucuronic acid → soluble bilirubin→ excreted with bile.
  Excreted bilirubin is transformed in small intestine into urobilinogen.
  1. Some urobilinogen is absorbed to be re-excreted again with bile).
  2. Some Urobilinogen is excreted with urine (giving red color of urine).
  3. Some Urobilinogen excreted with feces (giving brown color of feces).
- Iron is reused to form new Hb molecules.

Blood Groupings (ABO)

- In order to determine blood type, blood must be centrifuged to separate blood components.
- ABO blood group is based on presence (or absence) of two major agglutinogens (antigen) on RBC membranes - agglutinogen A & agglutinogen B.
- A person's erythrocytes contain one of four agglutinogen combination as a result of inheritance: only A, only B, both A & B or neither A nor B.
- A person with only agglutinogen A has type A blood. A person with only agglutinogen B has type B blood. A person with both agglutinogen A & B has type AB blood. A person with neither agglutinogen A nor B has type O blood.
- If a person has type A blood, his blood will contain antibodies (Ab) against agglutinogen B. These Abs called agglutinins. Conversely, type B person will have Ab against agglutinogen A.
- Blood compatibility can be predicted by understanding differences between donor & recipient blood types.
- 

Rh factor: it is another antigen (often called D) that may be present on RBCs.

- People whose RBCs have Rh antigen are Rh +ve;
- People without Rh antigen are Rh - ve.
- Rh -ve people do not have natural antibodies to Rh antigen, & for them this antigen is foreign.
- If an Rh -ve person receives Rh +ve blood by mistake, antibodies will be formed just as they would be to bacteria or viruses.

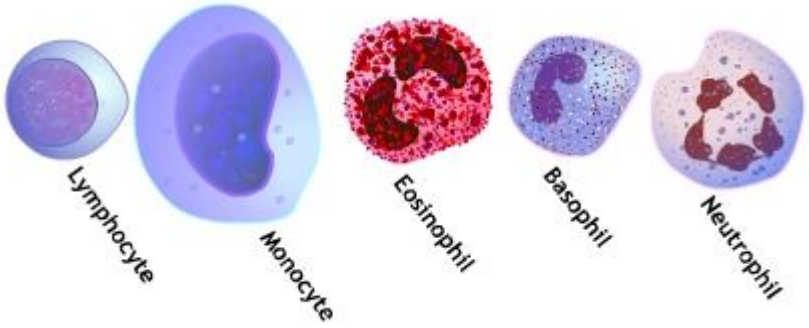
- A 1st mistaken transfusion often does not cause problems, because antibody production is slow upon the 1st exposure to Rh +ve RBCs.
- A 2nd transfusion, when anti-Rh antibodies are already present, will → transfusion reaction, with hemolysis.

Example : Hemolytic Disease of the Newborn

1. Before or during delivery, Rh +ve RBC of fetus enter blood of Rh –ve mother through placenta.
2. Mother is sensitized to Rh antigen & produces Rh antibodies. Because this usually happens after delivery, there is no effect on fetus in the first pregnancy.
3. During a subsequent pregnancy with Rh +ve fetus, Rh antibodies from mother cross placenta, causing agglutination & hemolysis of fetal RBC.

Leukocyte (white Blood Cell - WBC)

- There are 2 types of leukocytes; granulocytic & agranulocytic.
- *Granulocytic* type divided into 3; neutrophils, eosinophils & basophils.
- *Agranulocytic* type divided into 2; monocytes & lymphocytes.
- Granular white blood cells are produced in the bone marrow, while agranular white blood cells are produced in lymph tissue, e.g., Lymph nodes
- All WBC contain nucleus (multilobular in granulocytic & monolobular in agranulocytic).
- do not contain hemoglobin
- Cytoplasm may be granular (granules contain enzymes).



Neutrophils (microphages***):***

Have a major role in inflammation, it is the 1st cells to migrate to site of infection. Mainly concerned with phagocytosis. Plasma half-life (6 hrs), then migrate to tissues. It ingest (5-25 bacteria)

Monocytes (tissue macrophages) ***:***

Also phagocytic. It remains in blood for 24 hrs after which it migrates to tissues. They form 2nd line of defense against infection. It can engulf (100 bacteria). They also involved in immune system .

Eosinophils:

Predominate in tissues, remain in blood 8-12 hrs, then migrate to tissues. *Function:*

1. Mainly Detoxification of foreign proteins as in allergic conditions.
2. ↑ in parasitic manifestations.
3. They contain plasminogen, which is concerned in fibrinolytic activity (blood coagulation).

Basophils:

Remain in blood few hrs then leave to tissues. They contain histamine (causes inflammation) & receptors for immunoglobulin E (IgE) (basophils + IgE → histamine release → hypersensitivity). They also contain heparin (anticoagulant) so they ↑ in healing process.

Lymphocytes:

Play a major role in chronic infections (tuberculosis). At birth, few lymphocytes originate in bone marrow, while the majority arises in lymph node, thymus, & spleen from precursor cells , & enter blood stream through lymphatics. Types; B (Bursa of Fabricous) & T (thymus) lymphocytes.

WBC properties:

1- *diapedesis* :WBC can squeeze through pores of blood capillaries .
2- Ameboid motion By which WBC can move through the tissues.
3- Chemotaxis : process by which WBC**s** are attracted to inflamed tissue.
4- Phagocytosis: is cellular ingestion of the offending agent.

Phagocytosis. On approaching a particle to be phagocytized, neutrophil & macrophages attaches to a particle → projects pseudopodia in all directions around particle→ Pseudopodia meet one another & fuse → enclosed chamber → Chamber invaginates form a free-floating *phagocytic vesicle* (*phagosome*) inside cytoplasm. Lysosomes & other cytoplasmic granules come in contact with phagocytic vesicle→ their membranes fuse, thereby empty digestive enzymes & bactericidal agents into vesicle.

Much of killing effect results from powerful *oxidizing agents* formed by enzymes in membrane of phagosome or by a special organelle called *peroxisome.* These oxidizing agents are *superoxide*, *hydrogen peroxide* & *hydroxyl ions*.

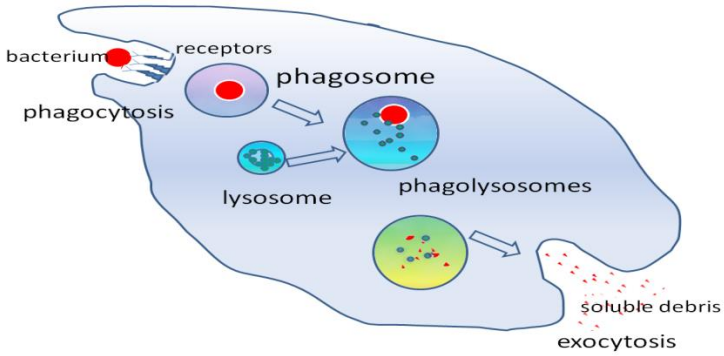
Macrophages are more powerful phagocytes than neutrophils through:

1-Macrophage phagocytize 100 bacteria, while neutrophil phagocytize 5-25 bacteria before it becomes inactivated & dies.

2- Macrophages have the ability to engulf much larger particles.

3-Macrophages can extrude residual products of phagocytosis & survive for many more months.

4- Lysosomes of macrophages (not of neutrophils) contain large amounts of *lipases,* which digest thick lipid membranes possessed by some bacteria such as tuberculosis bacillus.



Monocyte-Macrophage Cell System (Reticuloendothelial System)

After entering tissues & become macrophages, large portion of monocytes (having the same capability to phagocytize bacteria) attached to tissues for months or years until they are stimulated, so they break away from their attachment & become mobile macrophages again to perform local protective functions. Total combination of monocytes, mobile macrophages, fixed tissue macrophages, & a few specialized endothelial cells in bone marrow, spleen, & lymph nodes is called *reticuloendothelial system*.

Thrombocytes (Platelets)

- These are minute structures, with a regular shape (disk shaped).
- Formed in bone marrow from *megakaryocytes* (large cells); which fragment into minute platelets either in bone marrow or after entering blood.
- Have half life 8 -12 days then eliminated from circulation by tissue macrophage system,spleen.
- Play an important role in hemostasis (preventing blood loss)
- Do not have nuclei & cannot reproduce. but can secrete a variety of substances & can also contract (because they contain actin & myosin)
- On surface of its cell membrane is:
  1- A coat of *glycoproteins* that repulses adherence to normal endothelium, but causes adherence to *injured* areas of vessel wall.
  2- Contains large amounts of *phospholipids* that activate multiple stages in clotting process.

Hemostasis

It is the stoppage of bleeding, when blood vessels are damaged through several actions:

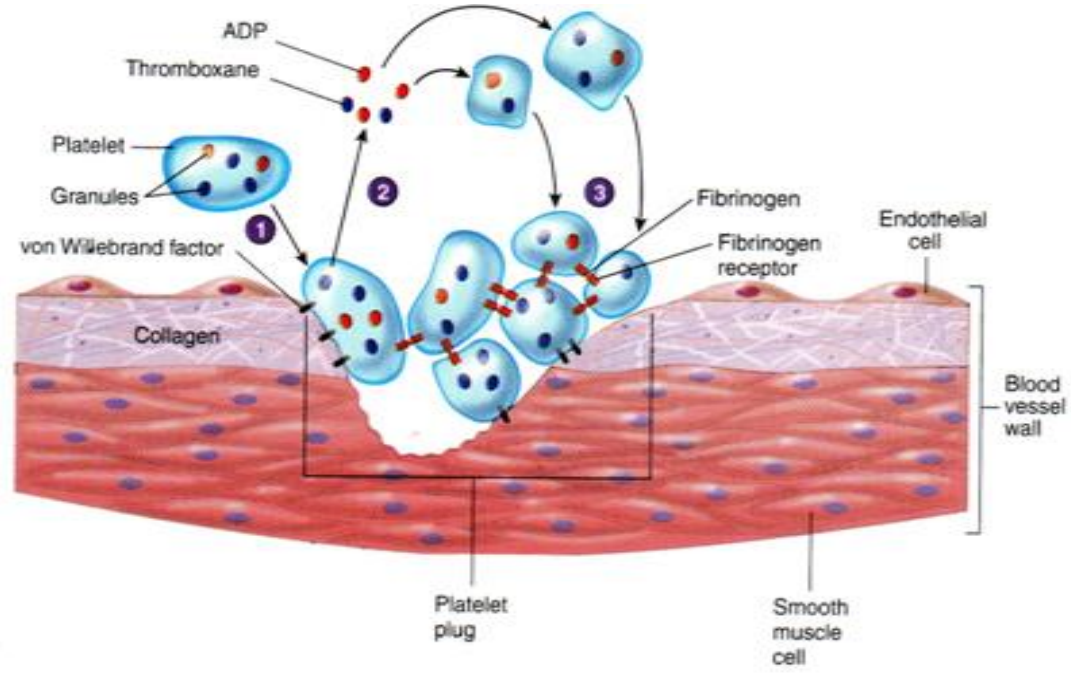
(a) Vasoconstriction reduces blood loss.

(b) Platelets adhere to the exposed collagen fibers of a vessel wall, forming a platelet plug.

(c) A clot forms as platelets & erythrocytes become enmeshed in fibrin threads.

- ☒ Following damage of small blood vessels, immediate reflex that promotes vasoconstriction occur, thus diminishing blood loss.
- ☒ Exposed collagen from damaged site will promote platelets to adhere.
- ☒ When platelets adhere to damaged vessel, undergo degranulation & release cytoplasmic granules, which contain **serotonin**,(a vasoconstrictor), ADP & Thromboxane A_2.
  ADP attracts more platelets to the area, & **thromboxane A_2** promotes platelet aggregation, degranulation→ promotes formation of a platelet plug.

- ☒ Damaged tissue releases also factor III, which with the aid of Ca^{++} will activate factor VII, thus initiating the extrinsic mechanism. Factor XII from active platelets will activate factor XI, thus initiating the intrinsic mechanism.



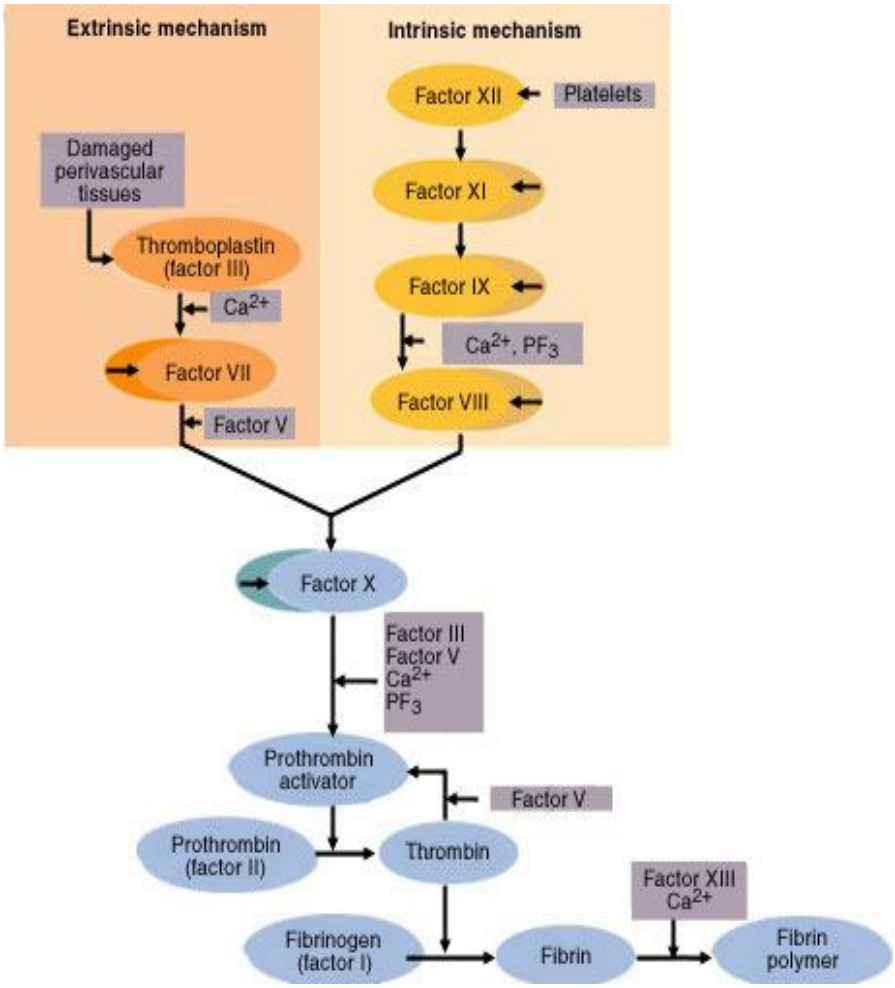
Clot Formation

Stage 1: Damage to tissue or blood vessels activates some clotting factors that activate other clotting factors, which leads to the production of prothrombinase.

Stage 2: Prothrombin is activated by prothrombinase to form thrombin.

Stage 3: Fibrinogen is activated by thrombin to form fibrin, which forms the clot.

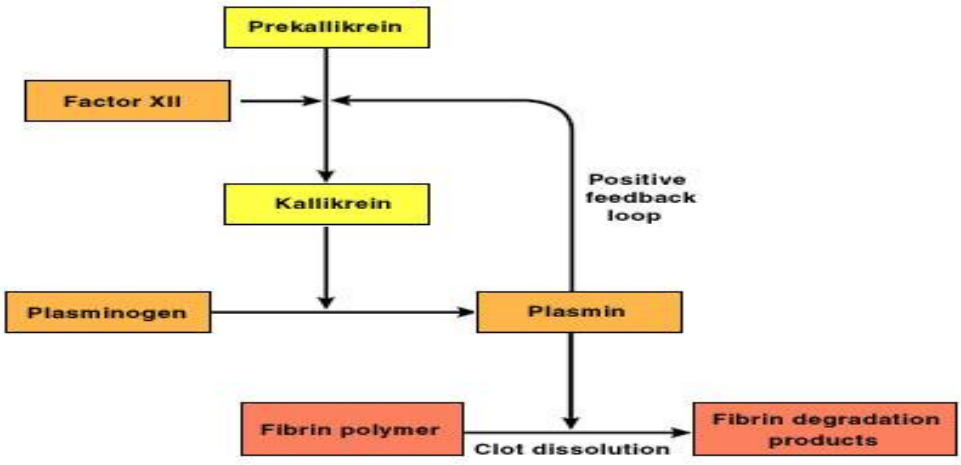
Fibrin initially forms a loose mesh, & then factor XIII causes formation of covalent cross links, which convert fibrin to a dense aggregation of fibers. Platelets & RBCs become caught in this mesh of fiber, thus the formation of a blood clot.



Platelet thromboplastic factor (PF_3)

Fibrinolysis

It is dissolution of a blood clot, that is achieved by a small cascade of reactions.
a- Factor XII,(which promotes clotting), also catalyzes formation of a plasma enzyme (kallikrin).
b- Kallikrin, in turn, converts inactive protein plasminogen → plasmin.
c- Plasmin breaks down fibrin molecules & therefore the clot into smaller pieces, which are washed away in blood or phagocytized.
d- Plasmin directly promotes the formation of more kallikrein, thus more plasmin.

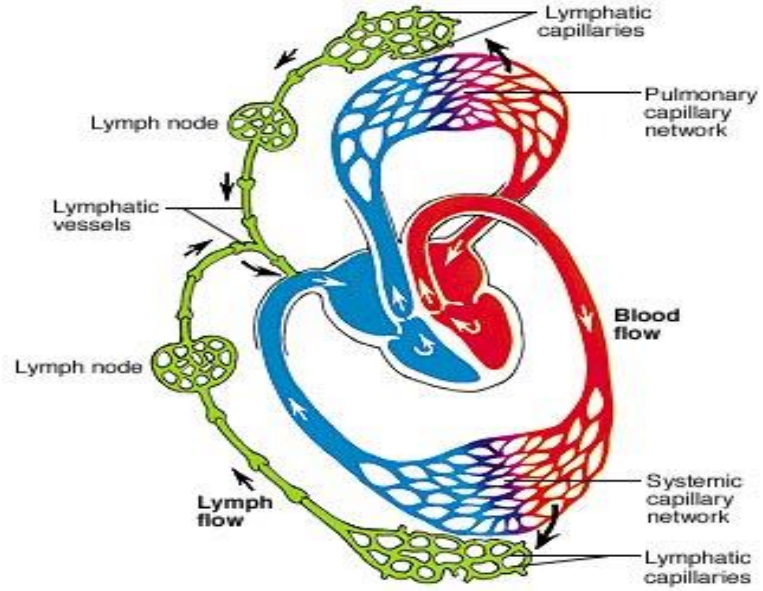


Lymphatic System

Lymphatic vessels transport fluid from interstitial spaces to the bloodstream.

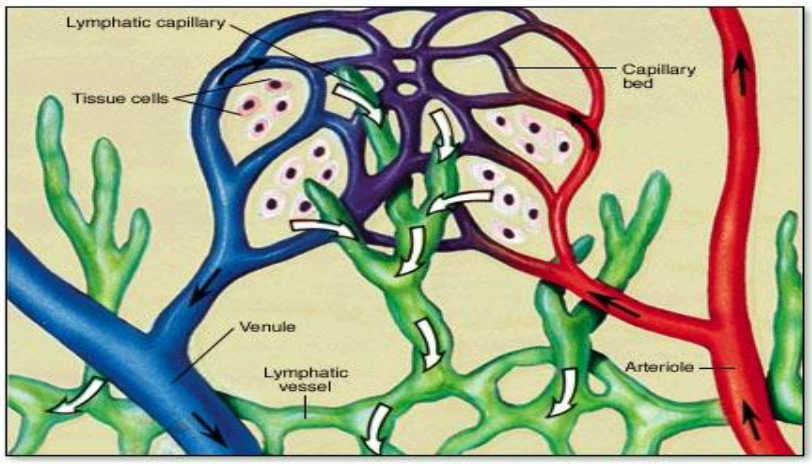
Function:

1- Carries fluid lost from capillaries. This fluid returns to blood in right lymphatic & thoracic ducts.
2- Transports products of fat digestion.
3- It is a major component of the immune system.



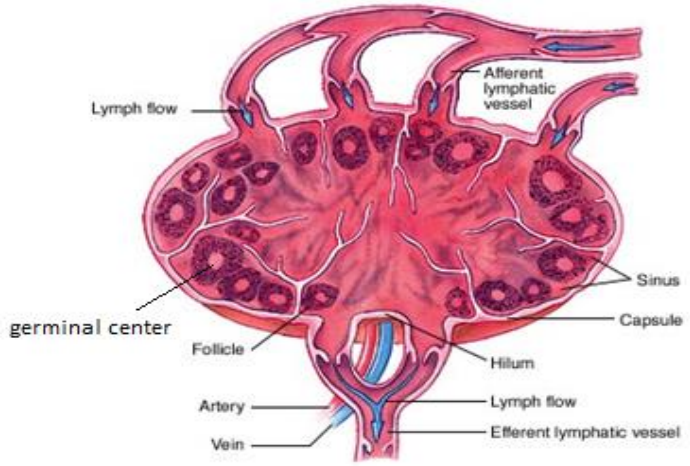
Lymph movement

- Lymphatic capillaries are microscopic, closed-ended tubes that begin in interstitial spaces of most tissues.
- Lymphatic vessels recycle excess tissue fluid that accumulates in interstitium as a result of normal capillary leakage.
- The walls of lymphatic vessels act as one-way valves, only letting fluid enter.
- Along the way, lymph is filtered through several lymph nodes where it is inspected for foreign substances.
- Upon reaching thoracic duct, lymph re-enters circulation.



Lymph nodes

They are lymph glands that located along lymphatic pathways. They contain large numbers of lymphocytes & macrophages that fight invading microorganisms, as lymph moves through. The germinal centers are sites of lymphocyte production.

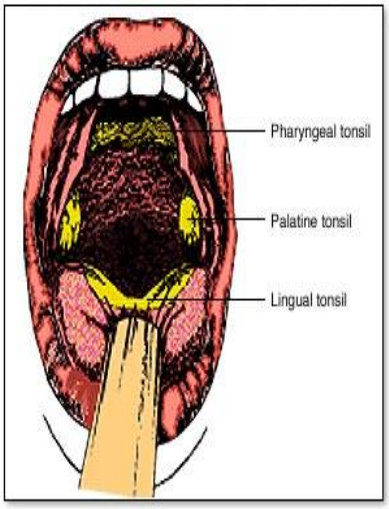


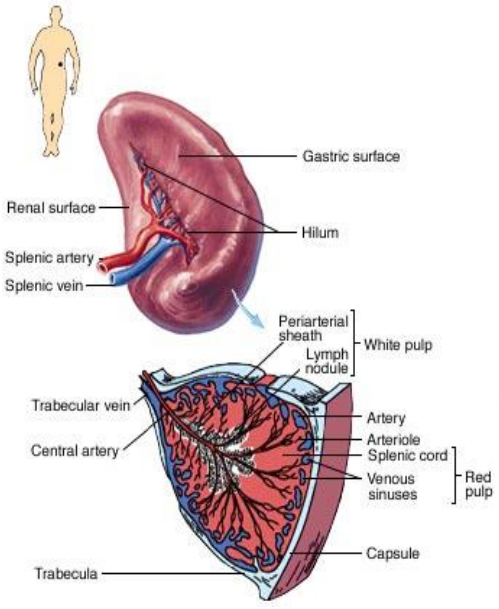
Lymph Organs

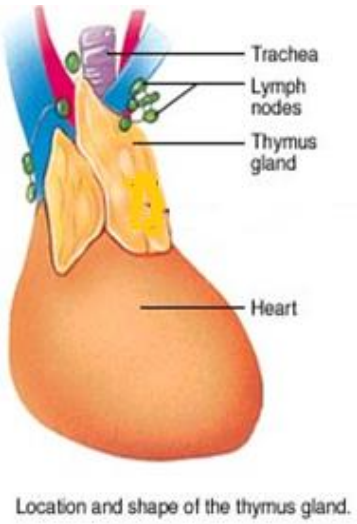
Tonsils: They are large groups of lymph nodules in the oral cavity & nasopharynx. The three groups of tonsils (a pair of palatine tonsils, a pair of lingual tonsils, & a single pharyngeal tonsil).

Spleen: Parenchyma of spleen consists of two types of tissue: red pulp & white pulp.
Red pulp consists of sinuses & destroys worn-out RBC.
White pulp consists primarily of lymphocytes & macrophage. Foreign substances in blood passing through white pulp & stimulate lymphocytes.

Thymus: It produces & matures T lymphocytes, which then move to other lymphatic tissues, where they can respond to foreign substances. Thymus secretes 2 Hs, thymopoietin & thymosins, which stimulate development & activity of T lymphocytes.







Location and shape of the thymus gland.

Introduction to Immune System

Pathogen : A disease-causing agent such as a virus or bacterial microorganism.

Antigen (Ag): foreign substance that elicits a specific immune response.

- Antigenic determinants are specific regions of Ag recognized by a lymphocyte.
- Antigens are divided into :
  a- Foreign antigens, introduced from outside. eg bacteria, viruses.
  b- Self-antigens: produced by the body that stimulates adaptive immunity. Response could be harmful (autoimmune disease) or beneficial (tumor distraction).

Lymphocyte : differentiated into B- Cells & T- cells:

- B-cells differentiate into plasma cells (give rise to antibodies) & memory B-cells.
- T-cells differentiate into helper/inducer T-cells; suppressor T-cells; cytotoxic T-cells (effector T-cells or killer cells) & memory cells.

Immunity (Body Defense)

- body's ability to resist or eliminate potentially harmful foreign materials or abnormal cells
- consists of following **activities**:
  - Defense against invading pathogens (viruses & bacteria)
  - Removal of 'worn-out' cells (e.g., old RBCs) & tissue debris (e.g., from injury)
  - Identification & destruction of abnormal or mutant cells (primary defense against cancer)
  - Rejection of 'foreign' cells (e.g., organ transplant)
  - Inappropriate responses:
    - Allergies - response to normally harmless substances
    - Autoimmune diseases

- Immunity is divided into: Innate (nonspecific immunity) &, adaptive (specific immunity).
- **Innate immunity:** Body recognizes & destroys certain foreign substances & the response to them is the same each time. Its main components are:
  1- **Mechanical** (Physical Barrier): e.g: skin, acidity of stomach, & cilia of respiratory tract.
  2- **Chemical** mediators:
  a- May found on surface of cells (e.g: lysozyme) .
  b- Others such as complements, prostaglandins, & cytokines.
  3-**Cells** involved in phagocytosis .

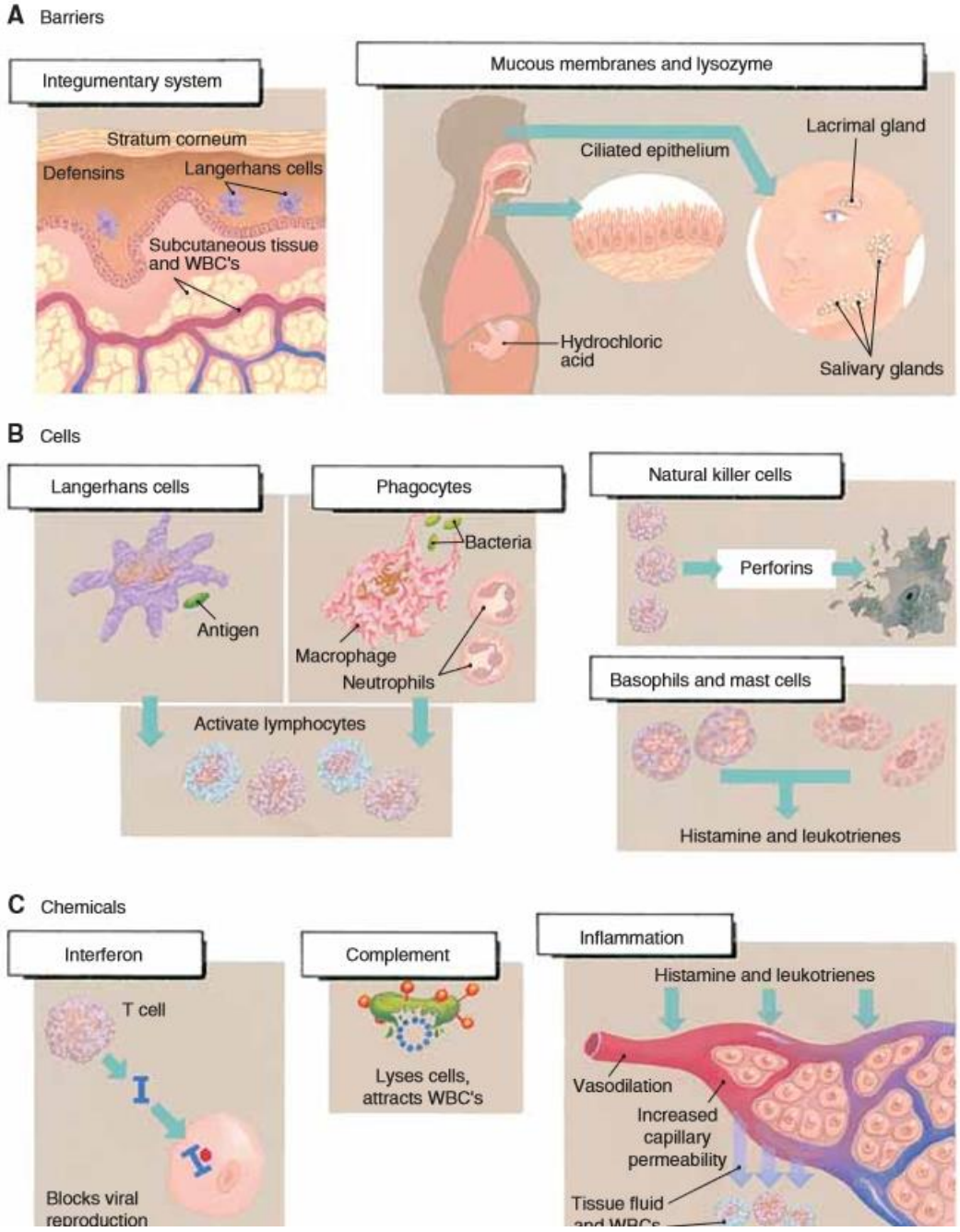
Natural Killer Cells (NK)

☒ It is a type of lymphocyte can recognize body cells with abnormal membranes, such as tumor cells & cells infected with virus, &, can destroy them on contact by secreting a protein that breaks down the cell membrane, but the way in which they find their targets is not yet completely understood.
☒ NK cells are found in the lymph nodes, spleen, bone marrow, and blood.

Interferon

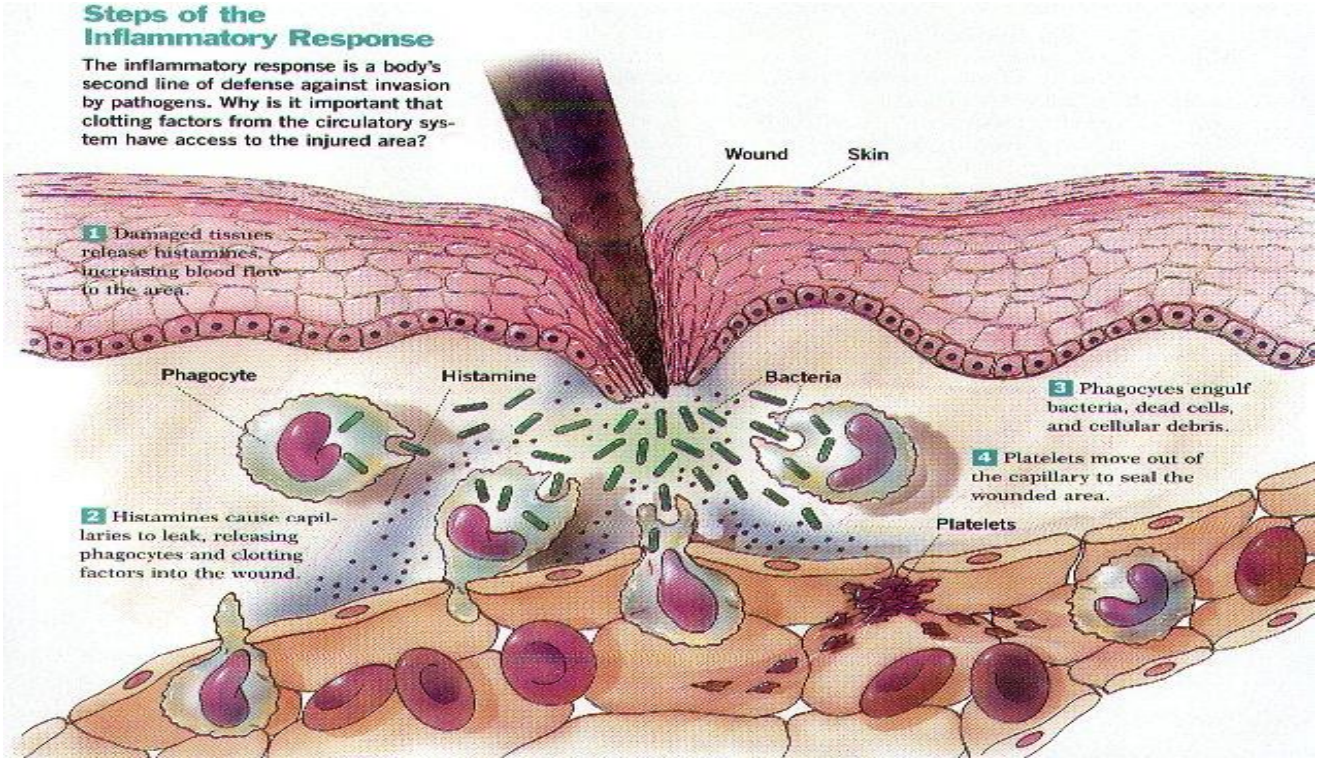
➢ Certain cells infected with a virus release a substance that prevents nearby cells from producing more virus. act nonspecifically on cells of the immune system
➢ It was called **interferon** because it "interferes" with multiplication and spread of the virus.
➢ Used to:
- treat certain viral infections, like hepatitis (produced by genetic engineering in m.o).

- Boost immune response in treatment of malignancies, such as leukemia, & cancer associated with AIDS.
- treat autoimmune disorder multiple sclerosis (MS), because it stimulates cells that depress the immune response.



Inflammation

- Can be caused by microbial infections, physical agents (e.g., trauma, UV radiation, burns)
- principle effects include:
  - **Heat** - is due to increased blood flow as a result of vascular dilation.
  - **Swelling** - results from edema (accumulation of fluid in the extra vascular space)
  - **Pain** - results partly from stretching & distortion of tissues due to edema and, in particular, from pus under pressure
- **function** is to destroy invaders & prepare area for healing & repair:



The Complement System

- A group of more than 20 plasma proteins that circulate in blood until activated. They are involved in the lysis of cellular antigens and the labeling of noncellular antigens. Some stimulate the release of histamine in inflammation; others attract WBCs to the site.

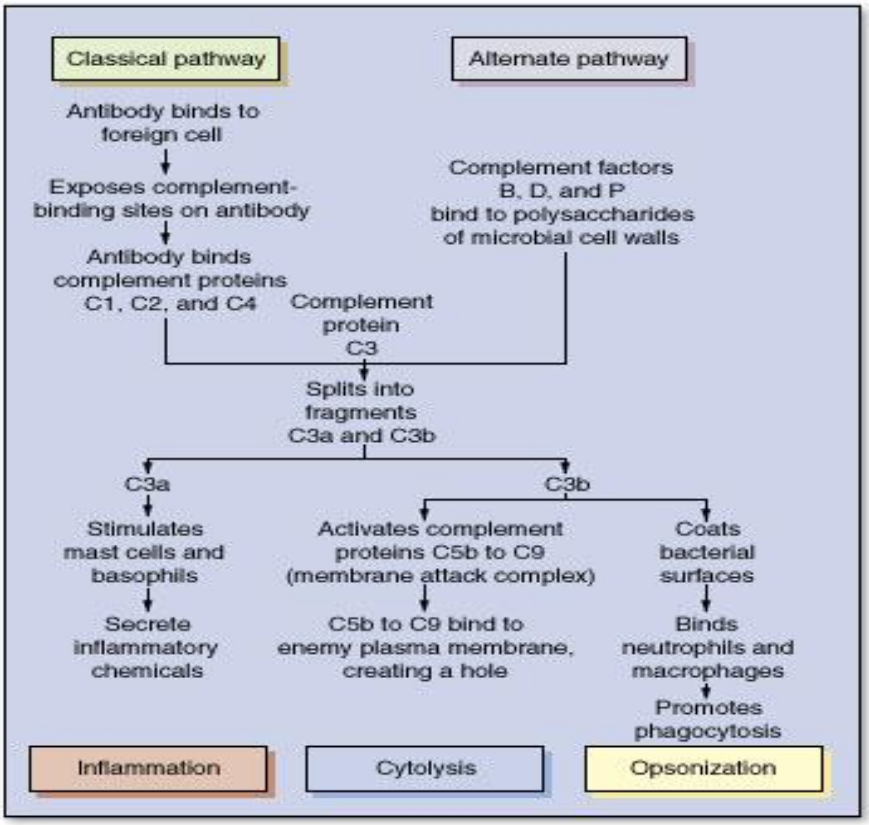
- They become activated when:

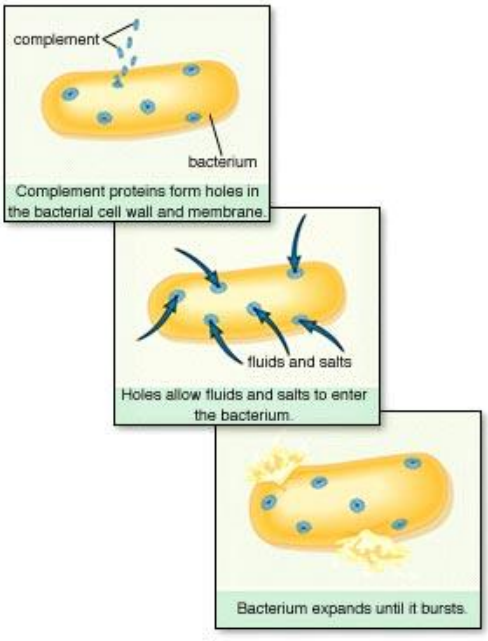
i. Certain proteins bind to (triggered by antibodies) an antigen-antibody complex (the classical pathway) or when:

ii. Other complement proteins bind to polysaccharides of the m.o (the alternate pathway).

Once activated, complement proteins enhance inflammatory response, form a membrane attack complex (MAC), which:

- destroys microbial membranes, or
- bind to microbial membrane to enhance phagocytosis, a process called opsonization.





Types of Cytokines

Cytokine	Function
Colony-stimulating factors	Stimulate bone marrow to produce lymphocytes
Interferons	Block viral replication, stimulate macrophages to engulf viruses, stimulate B cells to produce antibodies, attack cancer cells
Interleukens	Control lymphocyte differentiation and growth
Tumor necrosis factor	Stops tumor growth, releases growth factors, causes fever that accompanies bacterial infection, stimulates lymphocyte differentiation

Cytokines : they are polypeptides produced by virus-infected cells, stimulate many parts of immune system including specific immunity.

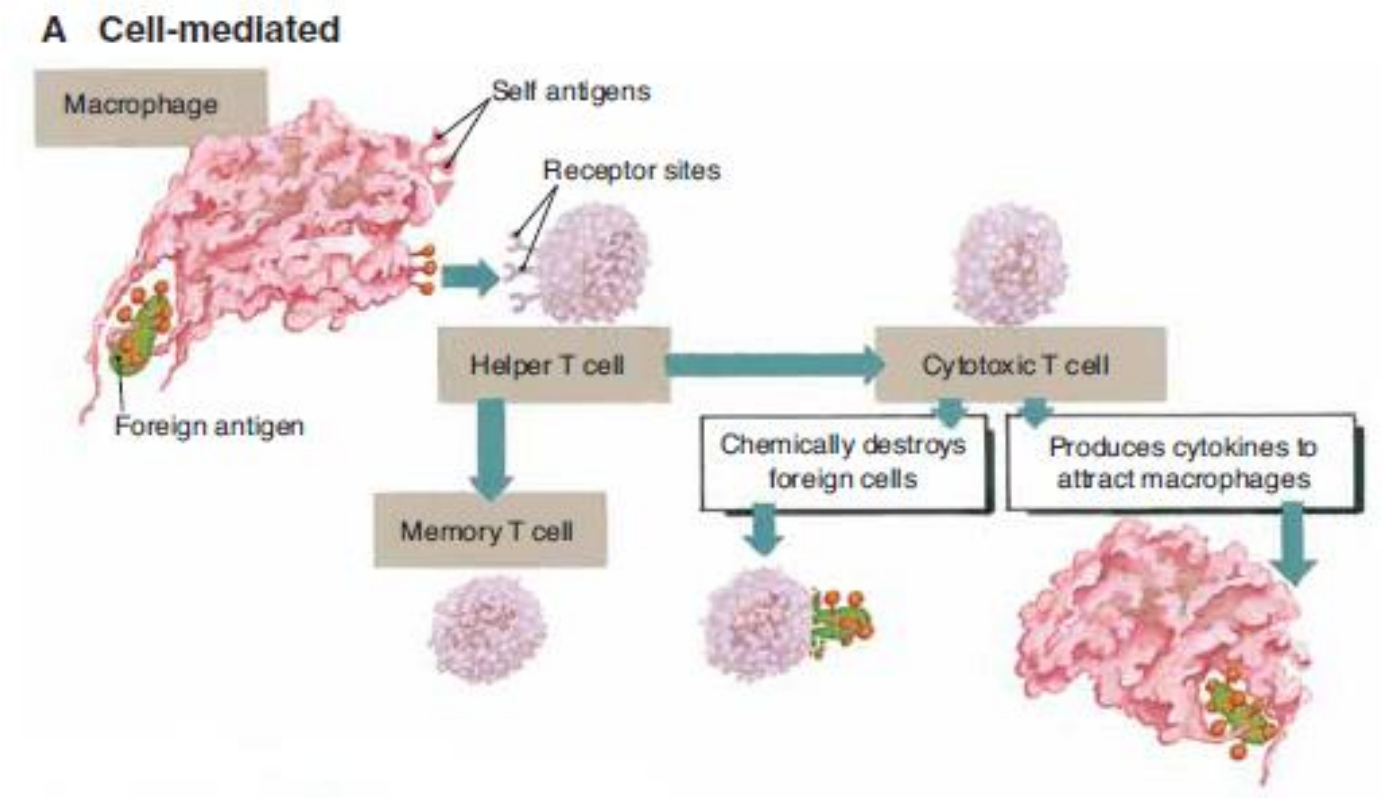
Specific Immune Responses (adaptive immunity)

- The ability to recognize, responds to, & remembers a particular substance or antigen.
- Adaptive immunity, response during 2nd exposure is faster & stronger than 1st exposure.
- Two classes of responses:
  - Humoral immunity - antibodies produced by B lymphocytes
  - Cell-mediated immunity - activated T lymphocytes
- Haptens are small molecules capable of combining with larger molecules like blood proteins to stimulate adaptive immune response. E.g of Hapten is Pencillin.
- Lymphocytes originate as stem cells in the bone marrow.
  Some migrate to the Thymus & develop into T-cells; others remain in the bone marrow & develop into B-cells.
- **B lymphocytes (or B cells)** are most effective against bacteria & their toxins + a few viruses, while **T lymphocytes (or T cells)** recognize & destroy body cells gone awry, including virus-infected cells & cancer cells.

Cell-Mediated Immunity

It does not result in production of Abs, but it is effective against intracellular pathogens (e.g virus), fungi, malignant cells& grafts of foreign tissue.

- 1st is recognition of foreign Ag by macrophages & helper T cells (called CD4 T cells), which become activated. These activated T cells, which are antigen specific, divide many times to form **memory T cells** & **cytotoxic** (**killer**)**T cells** (called CD8 T cells).
- Memory T cells will remember the specific foreign Ag & become active if it enters the body again, & will quickly initiate cell-mediated immune response.
- Cytotoxic T cells are able to chemically destroy foreign Ags by:
  a- Disrupting cell membranes..
  b- Also produce cytokines, which attract macrophages to the area & activate them to phagocytize the foreign Ag & cellular debris.
  - CD4 & CD8 T cells also produce feedback chemicals to limit the immune response once the foreign antigen has been destroyed.



Antibody-Mediated Immunity

This mechanism of immunity does involve the production of antibodies.

- 1st step is recognition of foreign Ag by B cells as well as by macrophages & helper T cells.
- The sensitized helper T cell presents the foreign Ag to B cells, which provides a strong stimulus for activation of B cells specific for this Ag.
- Activated B cells begin to divide many times,& 2 types of cells are formed.

Some of the new B cells produced are **memory B cells**, which will remember the specific Ag & initiate a rapid response upon a second exposure.

Other B cells become **plasma cells** that produce Abs specific for this foreign Ag.

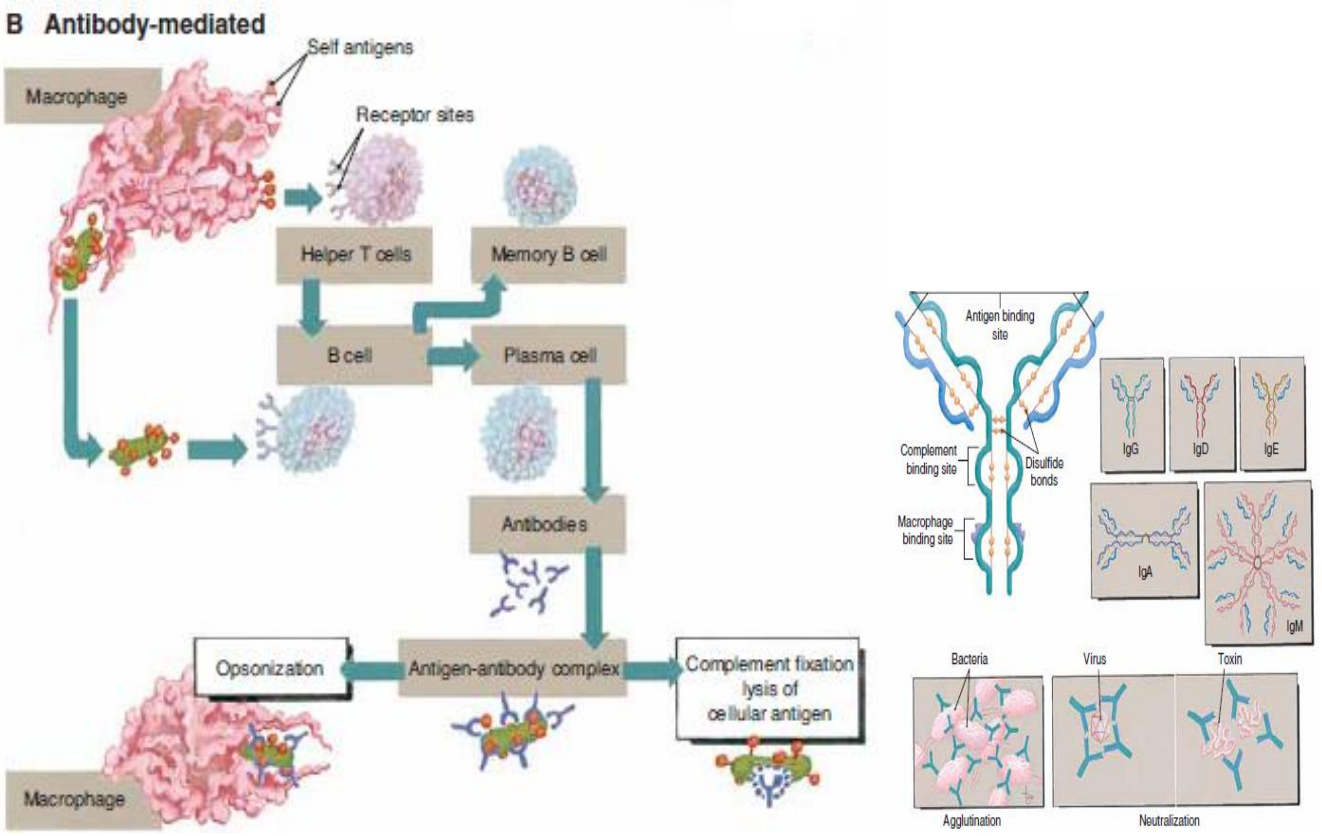
- **Antibodies**, called **immune globulins** Ig or **gamma globulins**, are proteins shaped (letter Y).
- Antibodies do not themselves destroy foreign Ags, but rather become attached to such Ags to "label" them for destruction. Each Ab produced is specific for only one Ag.
- Abs produced bond to the Ag, forming an Ag–Ab complex. This complex results in **opsonization**, which means that the Ag is now "labeled" for phagocytosis by macrophages or neutrophils.
- Ag–Ab complex also stimulates the process of ***complement fixation***.

Some of circulating complement proteins are activated, or fixed, by Ag–Ab complex. Complement fixation may be complete or partial.

If the foreign Ag is cellular, complement proteins bond to Ag–Ab complex, then to one another, forming a hole in the cell →death of the cell. This is **complete** complement fixation (it is also the cause of hemolysis in a transfusion reaction).

If the foreign Ag is not a cell— e.g virus—**partial** complement fixation takes place, in which some of complement proteins bond to the Ag–Ab complex. This is a chemotactic factor.

- *Chemotaxis* :is another label that attracts macrophages to engulf & destroy foreign Ag.

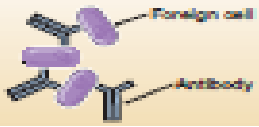
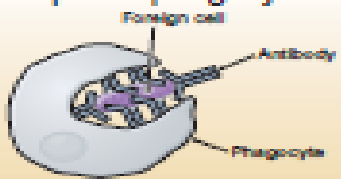


Antibody Responses

- 1st exposure to a foreign Ag does stimulate Ab production, but Ab are produced slowly & in small amounts. E.g On a person's 1st exposure to Measles virus, Ab production is too slow to prevent the disease itself, & person will have clinical measles. Most people who get measles recover, & upon recovery have Abs & memory cells that are specific for measles virus.
  On 2nd exposure to this virus, memory cells initiate rapid production of large amounts of Abs, enough to prevent a second case of measles. This is the reason why we develop immunity to certain diseases, & this is also the basis for the protection given by **vaccines.**

- As mentioned previously, antibodies label pathogens or other foreign Ag for phagocytosis or complement fixation. More specifically, Ab cause agglutination or neutralization of pathogens before their eventual destruction. **Agglutination** means "clumping," when Abs bind to bacterial cells. Bacteria that are clumped together by attached Abs are more easily phagocytized by macrophages. The activity of viruses may be neutralized by Abs. A virus must get inside a living cell in order to reproduce itself. However, a virus with Abs attached to it, is unable to enter a cell, cannot reproduce, & will soon be phagocytized. Bacterial toxins may also be neutralized by attached Abs.
- Abs change the shape of toxin, prevent it from exerting its harmful effects, & promote its phagocytosis by macrophages. **Allergies** are also the result of antibody activity.

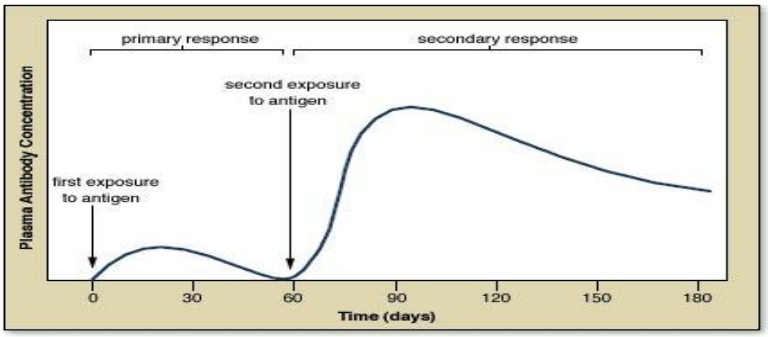
Antigen-Antibody Interactions and Their Effects

Interaction	Effects
Prevention of attachment 	A pathogen coated with antibody is prevented from attaching to a cell.
Clumping of antigen 	Antibodies can link antigens together, forming a cluster that phagocytes can ingest.
Neutralization of toxins 	Antibodies bind to toxin molecules to prevent them from damaging cells.
Help with phagocytosis 	Phagocytes can attach more easily to antigens that are coated with antibody.
Activation of complement 	When complement attaches to antibody on a cell surface, a series of reactions begins that activates complement to destroy cells.
Activation of NK cells 	NK cells respond to antibody adhering to a cell surface and attack the cell.

Suppressor T cells (also called Regulatory T cells):

- limit responses of other cells
- prevents excessive immune response which might be detrimental to body

Primary response vs. Secondary response:



Active immunity vs. Passive immunity

Passive Immunity:

direct transfer of antibodies formed by another person (or animal), e.g., transfer of IgG antibodies from mother to fetus across placenta or in colostrum ('first milk') OR treatment for rabies or snake venom. Infants are born with relatively weak immune responses. They have, however, a natural "passive" immunity; they are protected during the first months of life by means of antibodies they receive from their mothers. IgG, which travels across the placenta, makes them immune to the same microbes to which their mothers are immune. Children who are nursed also receive IgA from breast milk; it protects the digestive tract.

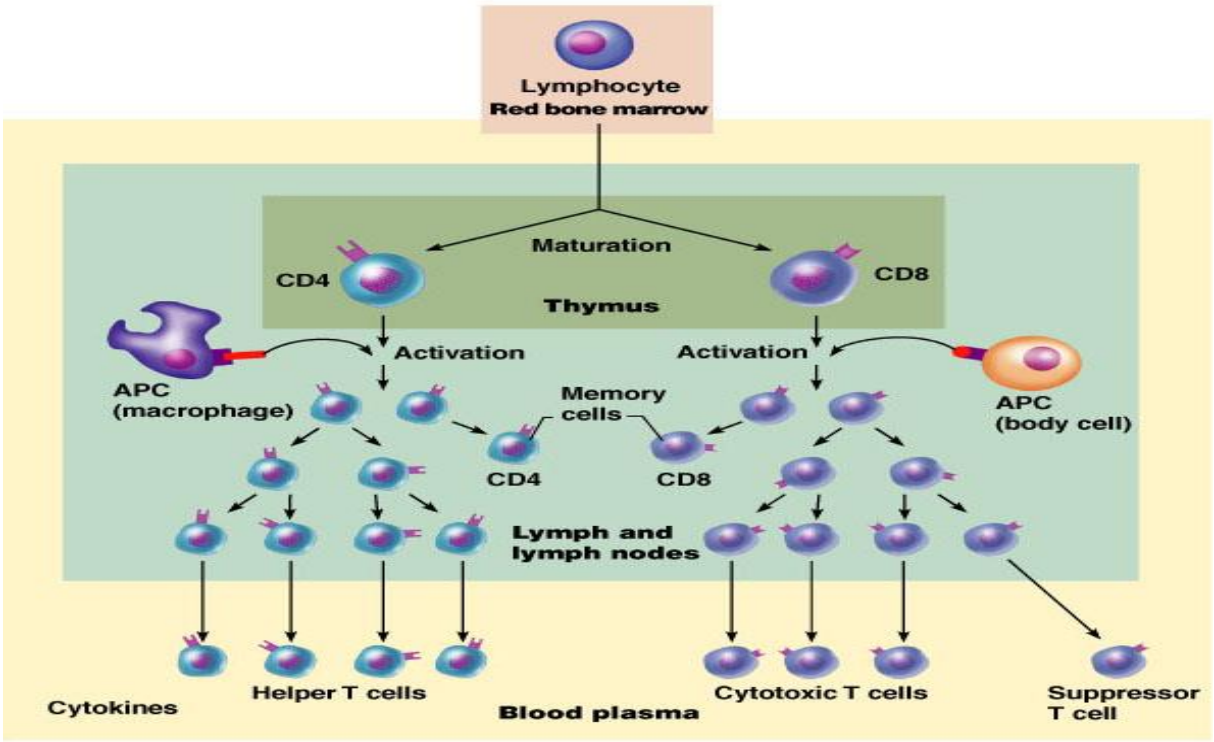
Passive immunity can also be conveyed by antibody-containing serum obtained from individuals who are immune to a specific infectious agent. Immune serum globulin or "gamma globulin" is sometimes given to protect travelers to countries where hepatitis is widespread.

Passive immunity typically lasts only a few weeks.

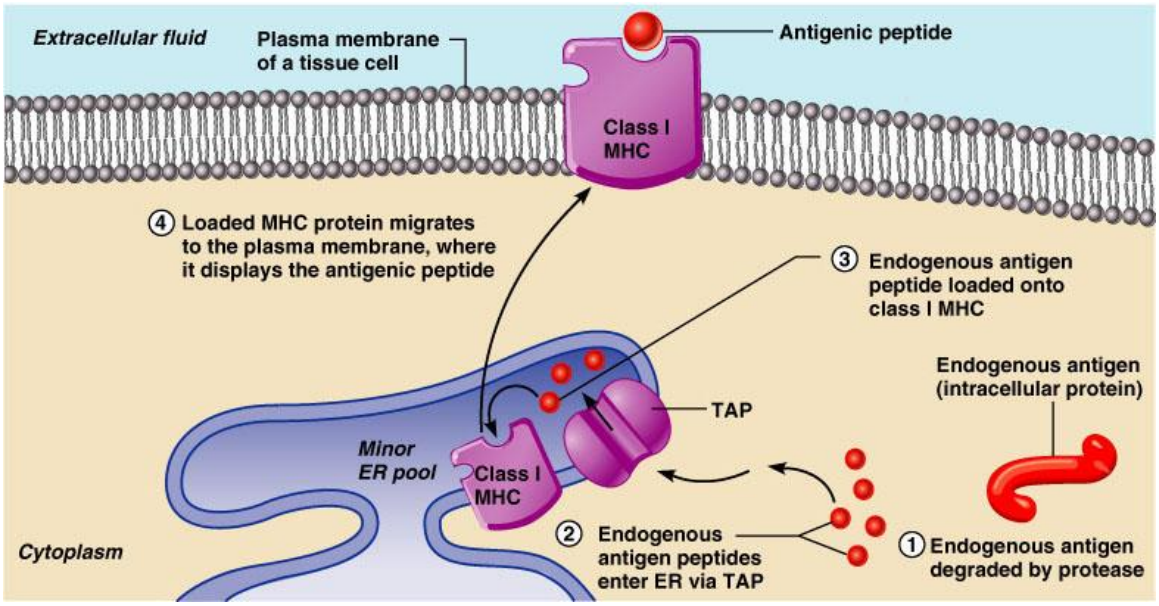
Active" immunity ('natural') = production of antibodies as a result of exposure to an antigen (immunization) and vaccination.

Vaccines contain microorganisms that have been altered so they will produce an immune response but will not be able to induce full-blown disease.

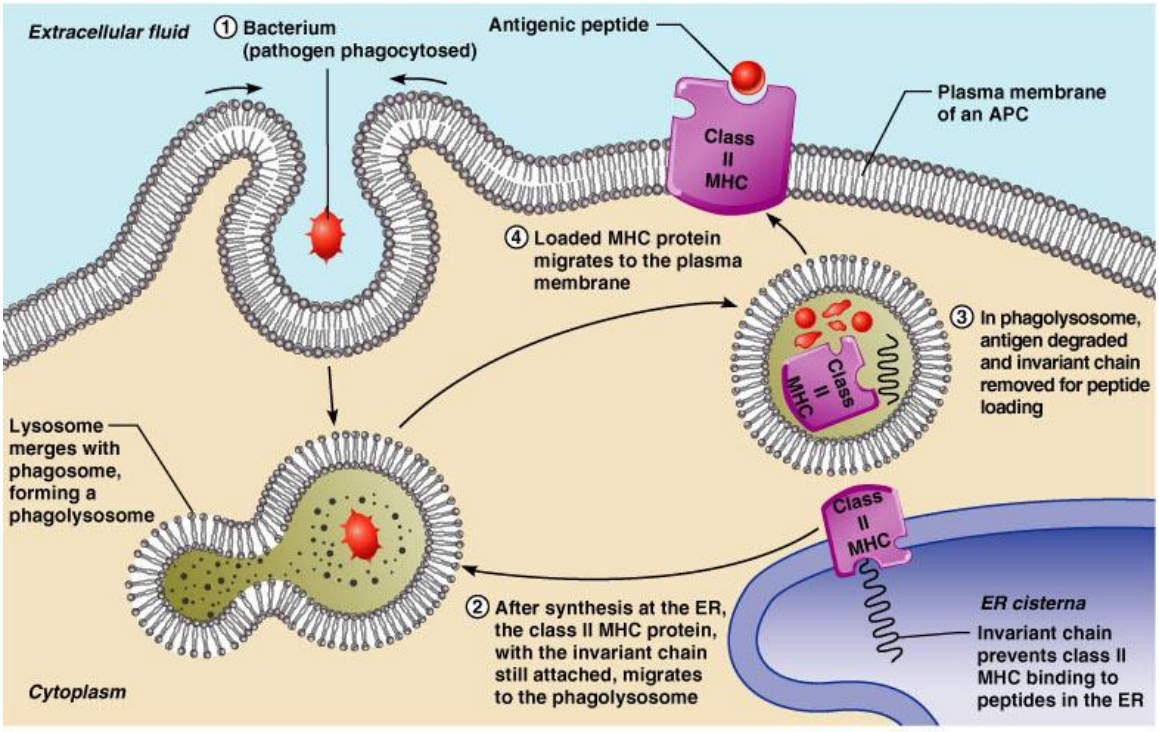
- ☒ Some vaccines are made from microbes that have been killed.
- ☒ Others use microbes that have been changed slightly so they can no longer produce infection. They may, for instance, be unable to multiply.
- ☒ Some vaccines are made from a live virus that has been weakened, or attenuated, by growing it for many cycles in animals or cell cultures.



Class I MHC Proteins



Class II MHC Proteins



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