Blood: Composition and Function
Blood Characteristics

• More viscous than water, flows slowly than water

• 8 % of total body weight

• Blood volume
  - 5 to 6 l in male
  - 4 to 5 l in female
Function of Blood

- Transportation
  - $O_2$, $CO_2$, metabolic wastes, nutrients, hormones
- Regulation
  - temperature, pH, fluid volume
- Protection from blood loss (platelets)
- Prevent infection (antibodies and WBC)
The blood components

- Plasma
- Red blood cells
- White blood cells
- Platelets
Colorized SEM of Red Blood Cells (red), platelets (green) and White Blood Cells (purple)
Blood Plasma

- 90% of water which dissolves and transports organic and inorganic molecules
- 10% dissolved solutes
  - Electrolytes
  - Nutrients
  - Organic wastes
- Proteins:
  - ALBUMINS – 80%, contribute to osmotic concentration
  - GLOBULINS – 16%, transport lipids and fat soluble vitamins
  - FIBRINOGEN – 4%, converts to insoluble fibrin in a blood clot
Formed Elements of Blood

- Red Blood Cells
- Leukocytes
- Platelets

Erythrocytes

Neutrophil

Lymphocyte

Monocyte

Eosinophil

Basophil

Platelets
Hematocrit

- The hematocrit is defined as the percentage of erythrocytes per unit level of blood.
- If whole blood is centrifuged, the cells and the plasma will separate.
- The erythrocytes, which are heavy, will pack into the bottom of the tube.
- The plasma will be at the top of the tube.
- The leukocytes and platelets will form a thin layer - **buffy coat** - between the erythrocytes and the plasma.

Plasma-55%

**Buffy coat**-<1%

**Formed elements**-45%
Erythrocytes
Erythro – red, Cytes - cells

• Biconcave discs, NO nucleus

• Inner plasma membrane protein – spectrin, responsible for the biconcave shape

• Special shape enlarges surface to volume ratio and allows to squeeze through capillaries

• Filled with hemoglobin, the protein that binds oxygen and CO2 for transportation

• Outer plasma membrane proteins are responsible for blood types(ABO system)

• Number – 4 to 6 millions in 1 µL

• Life span of about 120 days
Hemoglobin

HEMOGLOBIN

HEME=IRON

GLOBIN=PROTIEN

Red blood cell

Hemoglobin carries oxygen throughout the body

Oxygen molecule

Hemoglobin

α chain

iron

β chain

helical shape of the polypeptide molecule

ap Adam
Whyte blood cells
Leukocytes

- Protect the body from infectious microorganisms
- Diapedesis – circulating leukocytes leave the capillaries
- Function outside the bloodstream in loose connective tissue
- WBCs have a nucleus and are larger than RBCs
- Most produced in bone marrow
- Lifespan of several hours in the bloodstream to several days in the tissue
Diapedesis – circulating leukocytes leave the capillaries and enter the surrounding tissue in response to inflammation.
Whyte blood cells

Leukocytes

Granulocytes

Neutrophils- 40-70%
Eosinophils- 1-4%
Basophils- <1%

Agranulocytes

Monocytes- 4-8%
Lymphocytes- 20-45%

6,000-10,000 cells/µL
Granulocytes

- Contain specific granules and azurophilic granules
- Depending on the staining properties of granules, they can be divided into:

  - **Neutrophils** – 40-70%, neutral granules, multilobulated nucleus
  
  - **Eosinophils** – 1-4%, basic granules, bilobed nucleus
  
  - **Basophils** - < 1%, acidic granules, bilobed nucleus
• **Specific granules** (only granulocytes)
  - stained by neutral, acid or basic dyes
  - contain granules filled with different enzymes (alkaline phosphatase, major basic proteins, histamine, lysozyme)

• **Azurophilic granules** (both granulocytes and agranulocytes)
  - stained by azur dyes in purple color
  - are lysosomes, containing lytic enzymes
Neutrophils

- most numerous WBC
- Phagocytize and destroy bacteria
- Nucleus – has two to six lobes
- Granules pick up acidic and basic stains
Eosinophils

– compose 1 – 4% of all WBCs
– Nucleus has two lobes
– Numerous specific granules stained by eosin
– Play roles in allergic reactions, parasitic infections, can phagocytose Ag-Ab complexes
Basophils

– < 1% of all leukocytes
– Nucleus – usually two lobes
– Granules secrete histamines
– Involved in immediate hypersensitivity reaction, similar in function to mast cells
Granulocyte functions

- **GRANULOCYTES**
- **EOSINOPHILS** kill parasitic worms
- **EOSINOPHILS** also play a complex role in allergy and asthma
- **HALT, WORM!**
- **NEUTROPHILS** phagocytize bacteria
- **BASOPHILS** release histamine and other mediators of inflammation

Phil, don't do this!

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www.medcomic.com
Agranulocytes

- **Lymphocytes** – compose 20 – 45% of WBCs
  - The most important cells of the immune system
  - Nucleus – stains dark purple
  - Effective in fighting infectious organisms
  - Act against a specific foreign molecule (antigen)

- **Two main classes of lymphocyte**
  - **T cells** – attack foreign cells directly
  - **B cells** – multiply to become plasma cells that secrete antibodies
Agranulocytes

- **Monocytes** – compose 4–8% of WBCs
  - The largest leukocytes
  - Nucleus – kidney shaped
  - Transform into macrophages after migration into tissues
  - Phagocytic cells
# White Blood Cells

<table>
<thead>
<tr>
<th>Type Of White Blood Cells</th>
<th>% By Volume Of WBC</th>
<th>Description</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutrophils</td>
<td>60 – 70 %</td>
<td>Nucleus has many interconnected lobes; blue granules</td>
<td>Phagocytize and destroy bacteria; most numerous WBC</td>
</tr>
<tr>
<td>Eosinophils</td>
<td>2 – 4 %</td>
<td>Nucleus has bilobed nuclei; red or yellow granules containing digestive enzymes</td>
<td>Play a role in ending allergic reactions</td>
</tr>
<tr>
<td>Basophils</td>
<td>&lt; 1 %</td>
<td>Bilobed nuclei hidden by large purple granules full of chemical mediators of inflammation</td>
<td>Function in inflammation medication; similar in function to mast cells</td>
</tr>
<tr>
<td>Lymphocytes (B Cells and T Cells)</td>
<td>20 – 25 %</td>
<td>Dense, purple staining, round nucleus; little cytoplasm</td>
<td>the most important cells of the immune system; effective in fighting infectious organisms; act against a specific foreign molecule (antigen)</td>
</tr>
<tr>
<td>Monocytes</td>
<td>4 – 8 %</td>
<td>Largest leukocyte; kidney shaped nucleus</td>
<td>Transform into macrophages; phagocytic cells</td>
</tr>
</tbody>
</table>
Alteration of the ratio of different WBC:

**Decrease**
- Neutropenia
- Eosinopenia
- Basopenia
- Lymphopenia
- Monocytopenia

**Increase**
- Neutrophil
- Eosinophil
- Basophil
- Lymphocyte
- Monocytes
- Neutrophilia
- Eosinophilia
- Basophilia
- Lymphocytosis
- Monocytosis
Platelets

- Also called thrombocytes
- Blue-staining outer region (*hyalomere*), purple granules (*granulomere*), no nucleus
- Responsible for blood clotting and wound healing
- 200000-400000 cells/μL
- Life span is approximately 10 days
Blood clotting

1. Endothelium of vessel is damaged, exposing connective tissue; platelets adhere
2. Platelets form a plug
3. Seal is reinforced by a clot of fibrin

- Collagen fibers
- Platelet releases chemicals that make nearby platelets sticky

Clotting factors from:
- Platelets
- Damaged cells
- Plasma (factors include calcium, vitamin K)

Prothrombin → Thrombin

Fibrinogen → Fibrin

Fibrin clot
Red blood cell

5 μm
Blood Clot

- Platelet
- Fibrin thread
- RBC
Hematopoiesis

- Formation of blood cells
- Mainly takes place in the red bone marrow
- All blood cells arise from the same bone marrow stem cell
Stem Cells

✓ Immortal, meaning they never die (at least not until you do).

✓ Undifferentiated, meaning they have not yet developed into a particular cell type.

✓ Stem cells are pluripotent, meaning they have the potential to become any type of blood cell.

✓ The immortal, undifferentiated, pluripotent stem cells give rise to erythrocytes, leukocytes and platelets.
Stages of Hematopoiesis

- **Primordial stage** – 3$^{rd}$ week of embryonic development, in the yolk sac, only erythrocytes are produced.

- **Hepatosplenothymic stage** – second month of development, all blood cell types.

- **Definitive stage** – by the 5$^{th}$ month bone marrow becomes the primary hematopoietic tissue.
Bone Marrow

- soft, spongy, tissue found in the hollow spaces in the interior of bones
- the average weight of this tissue is about 4% of the total body weight
- consists of stem cells, supported by reticular connective tissue called stroma, adipocytes and abundant sinusoidal capillaries through which mature blood cells enter the circulation
Erythropoiesis

- **Erythropoiesis**: red blood cell production

Phases in development:
1. Ribosomal hemoglobin synthesis
2. Hemoglobin accumulation
3. Ejection of the nucleus and formation of reticulocytes

*Reticulocytes enter the circulation and become mature erythrocytes*
Bone Marrow Smear with developing red blood cells

Black arrow = basophilic erythroblast

Green arrow = polychromatophilic erythroblasts
Erythropoietin (EPO)
Direct stimulus for erythropoiesis
Released by the kidneys in response to hypoxia
Granulopoiesis - Formation Of Granular Leukocytes (WBCs)

--This process occurs in bone marrow along side Erythropoiesis

--Two steps Simultaneously

(4) Nuclei condense to adult form (bi-lobed, multi-lobed, etc)

(5) The cell begins to synthesize and collect its specific granule population.
Neutrophilic myelocyte
Basophilic myelocyte
Eosinophilic myelocyte

Myeloblast

Promyelocyte
First azurophilic granules being secreted in Golgi apparatus

Myelocyte
Moderate number of azurophilic granules and initial production of specific granules in Golgi zone

Metamyelocyte
Abundant specific granules and dispersed azurophilic granules; Golgi apparatus reduced

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Lymphopoiesis

1. Hemocytoplasm
2. Lymphoid stem cell
3. Lymphoblast
4. Prolymphocyte
5. Lymphocyte
6. Plasma cells
Monocytopoiesis

**Monoblast**
- **Nucleus**: Round to oval; may be irregularly shaped
- **Nucleoli**: 1-2; may not be visible
- **Chromatin**: Fine
- **Cytoplasm**: Light blue to gray
- **Granules**: None

**Promonocytes**
- **Nucleus**: Irregularly shaped; folded; may have brain-like convolutions
- **Nucleoli**: May or may not be visible
- **Chromatin**: Fine to lacy
- **Cytoplasm**: Light blue to gray
- **Granules**: Fine azurophilic
- **Vacuoles**: May be present

**Monocytes**
- **Nucleus**: Variable; may be round, horseshoe shaped; often has folds producing “brainlike” convolutions
- **Nucleoli**: Not visible
- **Chromatin**: Lacy
- **Cytoplasm**: Blue-gray; may have pseudopods
- **Granules**: Many fine granules giving the appearance of ground glass
- **Vacuoles**: Absent to numerous
Thrombopoiesis

Hematopoietic stem cell → Promegakaryocyte → Megakaryocyte → Platelet
Bone Marrow Smear with Megakaryocyte forming platelets (P)
<table>
<thead>
<tr>
<th>Cell Type</th>
<th>Illustration</th>
<th>Description*</th>
<th>Number of Cell per mm³ (μl) of Blood</th>
<th>Duration of Development (D) and Life Span (LS)</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes</td>
<td><img src="image" alt="Erythrocyte" /></td>
<td>Biconcave, anucleate disc; salmon-colored; diameter 7–8 μm</td>
<td>4–6 million</td>
<td>D: 5–9 days LS: 100–120 days</td>
<td>Transport oxygen and carbon dioxide</td>
</tr>
<tr>
<td>Leukocytes</td>
<td><img src="image" alt="Leukocyte" /></td>
<td>Spherical, nucleated cells</td>
<td>4800–11,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granulocytes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Neutrophils</td>
<td><img src="image" alt="Neutrophil" /></td>
<td>Nucleus multilobed; inconspicuous cytoplasmic granules; diameter 12–14 μm</td>
<td>3000–7000</td>
<td>D: 7–11 days LS: 6 hours to a few days</td>
<td>Destroy bacteria by phagocytosis</td>
</tr>
<tr>
<td>• Eosinophils</td>
<td><img src="image" alt="Eosinophil" /></td>
<td>Nucleus bilobed; red cytoplasmic granules; diameter 12–15 μm</td>
<td>100–400</td>
<td>D: 7–11 days LS: about 5 days</td>
<td>Turn off allergic responses and kill parasites</td>
</tr>
<tr>
<td>• Basophils</td>
<td><img src="image" alt="Basophil" /></td>
<td>Nucleus bilobed; large blue-purple cytoplasmic granules; diameter 10–14 μm</td>
<td>20–50</td>
<td>D: 3–7 days LS: a few hours to a few days</td>
<td>Release histamine and other mediators of inflammation</td>
</tr>
<tr>
<td>Agranulocytes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lymphocytes</td>
<td><img src="image" alt="Lymphocyte" /></td>
<td>Nucleus spherical or indented; pale blue cytoplasm; diameter 5–17 μm</td>
<td>1500–3000</td>
<td>D: days to weeks LS: hours to years</td>
<td>Mount immune response by direct cell attack (T cells) or via antibodies (B cells)</td>
</tr>
<tr>
<td>• Monocytes</td>
<td><img src="image" alt="Monocyte" /></td>
<td>Nucleus U- or kidney-shaped; gray-blue cytoplasm; diameter 14–24 μm</td>
<td>100–700</td>
<td>D: 2–3 days LS: months</td>
<td>Phagocytosis; develop into macrophages in tissues</td>
</tr>
<tr>
<td>Platelets</td>
<td><img src="image" alt="Platelet" /></td>
<td>Discoid cytoplasmic fragments containing granules; stain deep purple; diameter 2–4 μm</td>
<td>150,000–500,000</td>
<td>D: 4–5 days LS: 5–10 days</td>
<td>Seal small tears in blood vessels; instrumental in blood clotting</td>
</tr>
</tbody>
</table>

*Appearance when stained with Wright's stain.
Lymphocyte subsets

- **CLP** (Common lymphoid precursor)
  - **T CELLS**
  - **B CELLS**

**T CELLS**
- **Th** (T Helper Cells)
  - Activate B cells and macrophages
- **CTL** (Cytotoxic T Cells)
  - Kill virus infected cells

**B CELLS**
- **PC** (Plasma Cells)
  - Produce antibodies
Blood

Endothelial macrophage

Monocytes

Tissues

Resident macrophage

Myeloid dendritic cells

Langerhans cells (skin)

Kupffer cells (liver)

Osteoclasts (bone)

Microglia (CNS)

Lymph nodes

Recruited macrophage

Antigen-non-specific elicited

Alternatively antigen activated

Classically antigen activated

β₁- and β₂-integrins

Immunoglobulin-family members

Selectins

EGF-TM7 receptors

Nature Reviews | Immunology
Immunity

• = the bodies ability to resist infection

• can be **natural** or **acquired**
Low mag of a palatine or lingual tonsil
Palatine Tonsil w/ SS non-K (arrow)

Pharyngeal Tonsil w/ Resp epith (arrow = nodule)
Lymphoid Organs

- Thymus Gland
- Tonsil
- Lymph Node
- Spleen
- Bone Marrow
- Lymphatic Vessel
- Red Bone Marrow
Lymph nodes

- Lymph nodes are small encapsulated organs located along the pathway of lymphatic vessels.
- Two types of lymphatic vessels serve the lymph node:
  1. Afferent lymphatic vessels convey lymph toward the node and enter it at various points on the convex surface of the capsule.
  2. Efferent lymphatic vessels convey lymph away from the node and leave at the hilum, a depression on the concave surface of the node that also serves as the entrance and exit for blood vessels and nerves.
Diagram of a lymph node
Low mag of a lymph node

Cx = cortex w/ lymphatic nodules (F); M = medulla; C = CT capsule
A lymphatic nodule with germinal center (GC)
FIGURE 14.15 - Photomicrograph of a palatine tonsil. a. This low-magnification photomicrograph shows an H&E−stained palatine tonsil. The stratified squamous epithelium that forms the surface of the tonsil dips into the underlying connective tissue in numerous places, forming tonsillar crypts. ×25. b. This higher-magnification photomicrograph of the rectangular area in a shows the stratified
FIGURE 14.13 - Photomicrograph of a lymphatic nodule. This photomicrograph shows a section of the wall of the small intestine (duodenum). Short villi and intestinal glands are present in the upper part of the micrograph. A lymphatic nodule (LN) occupies most of the remainder of the micrograph. The lighter central region of the nodule is the germinal center. The lymphocytes in the germinal center are larger than those in the denser region of the nodule. They have more cytoplasm, so, their nuclei are more dispersed, giving the appearance of a less compact cellular mass. ×190.
Figure 14.14: Photomicrograph of a lymph node. This photomicrograph shows the superficial cortex (SC), deep cortex (DC), and medulla (M) of the lymph node in a routine H&E preparation. The capsule (Cap) is composed of dense connective tissue from which trabeculae (T) penetrate into the organ. Below the capsule is the subcapsular sinus (SCS). It receives lymph from theffer lymphatic vessels that penetrate the capsule. The subcapsular sinus is continuous with the trabecular sinuses that course along the trabeculae. The superficial cortex contains the lymphatic nodules (LN). The deep cortex is medulla free. It consists of densely packed lymphocytes and contains the unique high endothelial venules (not visible at this magnification). The medulla consists of narrow strands of anastomosing lymphatic tissue called medullary cords (MC), which are separated by light-appearing spaces, the medullary sinuses (MS). The medullary sinuses receive lymph from the trabecular sinuses as well as lymph that has filtered through the cortical tissue. × 140.
Lymphocytes in the superficial cortex are organized into nodules.

• The parenchyma of the lymph node is divided into a cortex and medulla.
  ➢ The cortex consists of a dense mass of lymphatic tissue (reticular framework, dendritic cells, follicular dendritic cells, lymphocytes, macrophages, and plasma cells) and lymphatic sinuses, the lymph channels.
  ➢ The medulla is the inner part of the lymph node
The medulla of the lymph node

- The medulla of the lymph node consists of the medullary cords and medullary sinuses.
- Filtration of lymph in the lymph node occurs within a network of interconnected lymphatic channels called sinuses.
- The lymph node is an important site for phagocytosis and initiation of immune responses.
The reticular meshwork of the lymph node contains several types of cells that perform different functions in generating immune responses.
The thymus

- The thymus is a lymphoepithelial organ located in the superior mediastinum.
- Connective tissue surrounds the thymus and subdivides it into thymic lobules.
- The thymic parenchyma contains developing T cells in an extensive meshwork formed by epithelioreticular cells.
Low mag of the thymus

Cortex (C)
Medulla (M)
• Thymic or Hassall’s corpuscles (derived from epithelioreticular cells) are a distinguishing feature of the thymic medulla.
• The blood–thymus barrier protects developing lymphocytes in the thymus from exposure to antigens.
• The thymus is the site of T-cell education.
High mag of the medulla of the thymus

Dark nuclei = T-cells

Larger nuclei = endothelial reticular cells

Arrow = Hassell’s Corpuscle
The spleen

• The spleen filters blood and reacts immunologically to blood-borne antigens.

• The spleen is enclosed by a dense connective tissue capsule from which trabeculae extend into the parenchyma of the organ.
Most of the spleen consists of splenic pulp. Splenic pulp, in turn, is divided into two functionally and morphologically different regions: **white pulp** and **red pulp**, based on the color of fresh sections.
• White pulp consists of a thick accumulation of lymphocytes surrounding an artery.
• Red pulp contains large numbers of red blood cells that it filters and degrades.
• The splenic or venous sinuses are special sinusoidal vessels lined by rod-shaped endothelial cells.
The spleen performs both immune and hemopoietic functions.

- **Immune system functions of the spleen include**
  - antigen presentation by APCs (mostly dendritic cells and macrophages) and initiation of immune response;
  - activation and proliferation of B and T lymphocytes;
  - production of antibodies against antigen present in circulating blood; and removal of macromolecular antigens from the blood.
Hemopoietic functions of the spleen include:

- removal and destruction of senescent, damaged, and abnormal erythrocytes and platelets;
- retrieval of iron from erythrocyte hemoglobin;
- formation of erythrocytes during early fetal life; and storage of blood.
First lines of defence

**saliva**
antibacterial enzymes

**tears**
antibacterial enzymes

**skin** prevents entry

**stomach acid**
low pH kills harmful microbes

**mucus** linings traps dirt and microbes

“**good” gut bacteria** out compete bad
Second lines of defence

• Involves white blood cells

• Non-specific response
  – invading pathogens are targeted by macrophages

• Specific response
  – lymphocytes produce antibodies and kill infected cells
Some vocabulary:

- **Antibody**: a protein produced by the human immune system to tag and destroy invasive microbes.
- **Antigen**: any protein that our immune system uses to recognize “self” vs. “not self.”
- **Specific defenses**: are those that give us immunity to certain diseases.
Major players

• The major players in the immune system include:
  – Macrophage
  – T cells (helper, cytotoxic, memory)
  – B cells (plasma, memory)
  – Antibodies
Macrophages

- Larger than neutrophils.
- Found in the organs, not the blood.
- Made in bone marrow as monocytes, called macrophages once they reach organs.
- Long lived
- **Initiate** immune responses as they display antigens from the pathogens to the lymphocytes.
Phagocytosis

1. Chemotaxis and adherence of microbe to phagocyte.
2. Ingestion of microbe by phagocyte.
3. Formation of a phagosome.
4. Fusion of the phagosome with a lysosome to form a phagolysosome.
5. Digestion of ingested microbe by enzymes.
6. Formation of residual body containing indigestible material.

(a) Phases of phagocytosis
Lymphocytes

• Produce antibodies
• B-cells mature in bone marrow then concentrate in lymph nodes and spleen
• T-cells mature in thymus
• B and T cells mature then circulate in the blood and lymph
• Circulation ensures they come into contact with pathogens and each other
T and B lymphocytes

Generative lymphoid organs

Blood, lymph

Peripheral lymphoid organs

Common lymphoid precursor

B lymphocyte lineage

T lymphocyte lineage

Bone marrow

Im mature B lymphocytes

Mature naive T lymphocytes

Mature B lymphocytes

Recirculation

Lymph nodes

Spleen

Mucosal and cutaneous lymphoid tissues
Types of lymphocyte

**B lymphocyte**
- Neutralization of microbe, phagocytosis, complement activation

**Helper T lymphocyte**
- Activation of macrophages
- Inflammation
- Activation (proliferation and differentiation) of T and B lymphocytes

**Cytotoxic T lymphocyte (CTL)**
- Killing of infected cell

**Regulatory T lymphocyte**
- Suppression of immune response

**Natural killer (NK) cell**
- Killing of infected cell
B-Lymphocytes

• There are 10 million different B-lymphocytes, each of which make a different antibody.
• The huge variety is caused by genes coding for antibodies changing slightly during development.
• There are a small group of clones of each type of B-lymphocyte
Clonal Selection

Lymphocyte clones with diverse receptors arise in generative lymphoid organs

Clones of mature lymphocytes specific for many antigens enter lymphoid tissues

Antigen-specific clones are activated ("selected") by antigens

Antigen-specific immune responses occur
B -Lymphocytes

- Some activated B cells $\rightarrow$ PLASMA CELLS
  these produce lots of antibodies
- The antibodies travel to the blood, lymph, lining of gut and lungs.
- The number of plasma cells goes down after a few weeks
- Antibodies stay in the blood longer but eventually their numbers go down too.
Naive B cell

Short-lived plasma cells in lymphoid tissues

Germinal centre

Memory B cell

Long-lived plasma cells in bone marrow (or gut lamina propria)

IgM

IgG

IgA

IgE
Antibodies

- Also known as immunoglobulins
- The heavy and light chains are polypeptides
- The chains are held together by disulphide bridges
- Each antibodies has 2 identical antigen binding sites – variable regions.
- The order of amino acids in the variable region determines the shape of the binding site
Different Immunoglobulins
<table>
<thead>
<tr>
<th>Type</th>
<th>Number of ag binding sites</th>
<th>Site of action</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>IgG</td>
<td>2</td>
<td>Blood, Tissue fluid, CAN CROSS PLACENTA</td>
<td>Increase macrophage activity, Antitoxins, Agglutination</td>
</tr>
<tr>
<td>IgM</td>
<td>5</td>
<td>Blood, Tissue fluid</td>
<td>Agglutination</td>
</tr>
<tr>
<td>IgA</td>
<td>2 or 4</td>
<td>Secretions (saliva, tears, small intestine, vaginal, prostate, nasal, breast milk)</td>
<td>Stop bacteria adhering to host cells, Prevents bacteria forming colonies on mucous membranes</td>
</tr>
<tr>
<td>IgE</td>
<td>2</td>
<td>Tissues</td>
<td>Activate mast cells → HISTAMINE, Worm response</td>
</tr>
</tbody>
</table>
IgA

- Secretions (saliva, tears, small intestine, vaginal, prostate, nasal, breast milk)
Role of antibodies

- Antibodies released into the blood stream will bind to the antigens that they are specific for.
- Antibodies may disable some microbes, or cause them to stick together (agglutinate). They “tag” microbes so that the microbes are quickly recognized by various white blood cells.
Antibodies as Receptors

- Antibodies can attach to B cells, and serve to recognize foreign antigens.
• antibodies combine with their specific antigen (like a lock and key)

• this renders the pathogen harmless.
• = primary response
Antigens as Effectors

- Free antibodies can bind to antigens, which “tags” the antigen for the immune system to attack and destroy.
Antigen recognition

• Cells of the immune system are “trained” to recognize “self” proteins vs. “not self” proteins.

• If an antigen (“not self”) protein is encountered by a macrophage, it will bring the protein to a helper T-cell for identification.

• If the helper T-cell recognizes the protein as “not self,” it will launch an immune response.
T-Lymphocytes

- Mature T-cells have T cell receptors which have a very similar structure to antibodies and are specific to 1 antigen.
- They are activated when the receptor comes into contact with the Ag with another host cell (e.g. on a macrophage membrane or an invaded body cell)
T Cells

Resting helper T cell

Resting cytotoxic T cell

Activated helper T cell

Activated killer cell
T-Lymphocytes

• After activation the cell divides to form:
  • **T-helper cells** – secrete CYTOKINES
    → help B cells divide
    → stimulate macrophages
  • **Cytotoxic T cells** (killer T cells)
    → Kill body cells displaying antigen
  • **Memory T cells**
    → remain in body
Helper T cells

- Helper T-cells have receptors for recognizing antigens. If they are presented with an antigen, they release cytokines to stimulate B-cell division.
- The helper T-cell is the key cell to signal an immune response. If helper T-cells are disabled, as they are in people with AIDS, the immune system will not respond.
The Pathway of Specific Immune Response

Step 1
Pathogens eaten by Macrophage

Step 2
Displays portion of Pathogen on surface

Step 3
Helper-T cell recognizes Pathogen
Cell-mediated immunity (attack on infected cells)

Humoral immunity (secretion of antibodies by plasma cells)

Class II MHC molecule

T-cell receptor

Antigen fragment

Bacterium

APC (macrophage)

CD4

Interleukin-1 activates TH cells.

TH cell

TC cell

Interleukin-2 and other cytokines activate TH cells, B cells, and TC cells.

B cell

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“Killer” T cells

• While B-cells divide and differentiate, so do T-cells.
• Some T-cells become cytotoxic, or “killer” T-cells. These T-cells seek out and destroy any antigens in the system, and destroy microbes “tagged” by antibodies.
• Some cytotoxic T-cells can recognize and destroy cancer cells.
Immune Response Summary

**Antigen**
- Displays copy of antigen on surface of cell

**Macrophage**

**Helper T-Cell**

**Cellular Immunity**
- **Active Cytotoxic T-Cell**
  - Kills Infected Cells
- **Memory T-Cell**

**Antibody Immunity**
- **Active B-Cell**
- **Plasma Cell**
  - Antibodies
  - Deactivates Antigens
- **Memory B-Cell**
Passive and Active Immunity

1. **Active Immunity**
   This is immunity where the body is “actively” producing antibodies to fight infection.
   
   **Vaccination:** An injection of a *weakened strain* of an infectious microbe (pathogen) that causes the body to undergo active immunity (produce antibodies).

2. **Passive Immunity**
   This is immunity where antibodies are given to a person from the blood of another person or animal.
Vaccine history

- Vaccination: (From *vacca*, Latin for cow.) Invented by Edward Jenner in 1796. Jenner knew that dairy maids who had contracted cowpox never got smallpox. He inoculated a boy with secretions from cowpox sores, and showed the boy was immune to smallpox.
Allergies

Allergy
- An exaggerated response by the immune system to an allergen.

Allergen: a normally harmless substance that causes an allergic reaction.
ex: dust, pollen, mould, food, insect stings
What happens during an allergic reaction?

- During an allergic reaction antibodies cause *histamines* to be released from mast cells.

Histamines cause:
  a. Swelling of tissues
  b. Release of fluids (runny noses and eyes)
  c. muscle spasms (some cases)
Cartoons - “cow pock” vaccine.
Благодарю за внимание