• Blood consists of red and white blood cells suspended in plasma
  – Blood is about 55% plasma and 45% cellular elements

• Plasma
  – 90% water
  – 10% dissolved inorganic ions, proteins, nutrients, wastes, gases, and hormones

• Red blood cells (erythrocytes)
  – Transport $O_2$ bound to hemoglobin
### Plasma (55%)

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Major functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water</strong></td>
<td>Solvent for carrying other substances</td>
</tr>
<tr>
<td><strong>Salts (ions)</strong></td>
<td>Osmotic balance, pH buffering, and nerve and muscle function</td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td></td>
</tr>
<tr>
<td>Bicarbonate</td>
<td></td>
</tr>
<tr>
<td><strong>Plasma proteins</strong></td>
<td>Osmotic balance and pH buffering</td>
</tr>
<tr>
<td>Fibrinogen</td>
<td>Clotting</td>
</tr>
<tr>
<td>Immunoglobulins (antibodies)</td>
<td>Immunity</td>
</tr>
<tr>
<td><strong>Substances transported by blood</strong></td>
<td></td>
</tr>
<tr>
<td>Nutrients (e.g., glucose, fatty acids, vitamins)</td>
<td></td>
</tr>
<tr>
<td>Waste products of metabolism</td>
<td></td>
</tr>
<tr>
<td>Respiratory gases (O₂ and CO₂)</td>
<td></td>
</tr>
<tr>
<td>Hormones</td>
<td></td>
</tr>
</tbody>
</table>
### Cellular elements (45%)

<table>
<thead>
<tr>
<th>Cell type</th>
<th>Number per $\mu$L $\text{mm}^3$ of blood</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes (red blood cells)</td>
<td>5–6 million</td>
<td>Transport of oxygen (and carbon dioxide)</td>
</tr>
<tr>
<td>Leukocytes (white blood cells)</td>
<td>5,000–10,000</td>
<td>Defense and immunity</td>
</tr>
<tr>
<td>Basophil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eosinophil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymphocyte</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutrophil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monocyte</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelets</td>
<td>250,000–400,000</td>
<td>Blood clotting</td>
</tr>
</tbody>
</table>

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Too few or too many red blood cells can be unhealthy

– Red blood cells
  • Circulate for 3 to 4 months
  • Old cells are broken down and their components are recycled

– Anemia
  • An abnormally low amount of hemoglobin or red blood cells
  • Most commonly caused by iron deficiency
• White blood cells (leukocytes)  
  – Function both inside and outside the circulatory system to fight infections and cancer

• Platelets  
  – Cell fragments involved in clotting
• Blood clots plug leaks when blood vessels are injured
  – Blood clotting involves platelets, the plasma protein fibrinogen, and clotting factors
  – The clotting process
    1. Platelets adhere to exposed connective tissue
    2. Platelet plug forms
    3. Fibrinogen converted to fibrin, forms clot that traps blood cells
Platelets adhere to exposed connective tissue

Platelet plug forms

Fibrin clot traps blood cells
Blood-clotting malfunctions

• Hemophelia
  – Inherited disease
  – Blood doesn’t clot, and bleeding can be fatal

• Thrombus
  – Clot formed in the absence of injury
  – Can break free and lodge in a vessel, causing heart attack, stroke, or pulmonary embolism
Warfarin

Innate defenses against infection include the skin and mucous membranes, phagocytic cells, and antimicrobial proteins

- Innate immunity is the body’s first line of defense against all invaders
  - Skin provides tough barrier and general chemical defenses
  - Mucous membranes
  - Stomach acid
  - Hairs, cilia
Infections often start at mucous membranes

http://www.agen.ufl.edu/~chyn/age2062/lect/lect_25/FG19_001.GIF
• Microbes that breach the body's external defenses are confronted by innate defensive cells
  – Found in blood and interstitial fluid
  – Macrophages are large phagocytic cells
  – Natural killer cells release chemicals
  – Specific proteins attack microbes or impede their reproduction
    • Interferons help cells resist viruses

• The complement system
  – Initiated by microbes, can lead to lysis of invaders
The inflammatory response mobilizes nonspecific defense forces

- Tissue damage triggers the inflammatory response
  - Can disinfect tissues and limit further infection

- Steps of the inflammatory response
  1. Tissue injury releases chemical signals such as histamine
  2. Local blood vessels dilate and leakiness increases; phagocytes migrate to the area
1. Tissue injury; release of chemical signals such as histamine
2. Dilation and increased leakiness of local blood vessels; migration of phagocytes to the area
3. Phagocytes (macrophages and neutrophils) consume bacteria and cell debris; tissue heals
Phagocytes consume bacteria and cell debris; tissue heals

- The inflammatory response may be widespread as well as localized
  - White blood cells may increase
  - Fever may stimulate phagocytosis
  - Septic shock
- Overwhelming systemic inflammatory response
- May cause death
Adenoid
Tonsil
Lymph nodes
Right lymphatic duct, entering vein
Thoracic duct, entering vein
Thymus
Thoracic duct
Appendix
Spleen
Bone marrow
Lymphatic vessels
Lymphatic capillary
Lymph node
Masses of lymphocytes and macrophages
Valve
Lymphatic vessel
Blood capillary
Tissue cells
Interstitial fluid
• Main functions of the lymphatic system
  – Return tissue fluid to circulatory system
    • Lymphatic vessels take up fluid from tissue spaces
    • Lymph reenters circulatory system through two large lymphatic vessels
  – Fight infection
    • Microbes picked up from infection sites travel in lymph through lymphatic organs packed with white blood cells
The lymphatic system becomes a crucial battleground during infection

• The lymphatic system is involved in both innate and acquired immunity
  – Branching network of lymphatic vessels
  – Lymph nodes packed with macrophages and white blood cells
  – Tonsils and adenoids
  – Appendix
  – Spleen
  – Bone marrow and thymus
  – Lymph, similar to interstitial fluid
Virus  
Viral nucleic acid

1. Interferon genes turned on

2. Interferon molecules

3. DNA  
mRNA

4. Host cell 1  
Makes interferon; is killed by virus

5. Interferon stimulates cell to turn on genes for antiviral proteins

Host cell 2  
Protected against virus by interferon from cell 1

Antiviral proteins block viral reproduction
The Complement System

The first part of the immune system that meets invaders such as bacteria is a group of proteins called the *complement system*. These proteins flow freely in the blood and can quickly reach the site of an invasion where they can react directly with *antigens* - molecules that the body recognizes as foreign substances. When activated, the complement proteins can:

- trigger inflammation
- attract eater cells such as macrophages to the area
- coat intruders so that eater cells are more likely to devour them
- kill intruders
ACQUIRED IMMUNITY

The immune response counters specific invaders

- The immune system recognizes and defends against invading microbes and cancer cells
  - Can distinguish one infectious agent from another

- Acquired immunity develops only after exposure to a specific foreign substance (antigen)
  - System produces a specific type of antibody that helps counter the antigen's effects
  - Primed system remembers the antigen and reacts to it in the future
• Immunity is usually acquired by natural exposure to antigens but may be achieved by vaccination
  – Active immunity
    • Person's own immune system actively produces antibodies
  – Passive immunity
    • Person receives premade antibodies, as a fetus does from its mother
    • Immunity lasts only as long as the antibodies do
The End