Hematology
Basic scheme

- Blood leaves the heart in arteries
- Branching of arteries until they become tiny capillaries
  - Oxygen and nutrients diffuse out
  - CO2 and wastes diffuse in
- Capillaries form veins going to the heart
- The blood leaves the right side of the heart for the lungs to pick up O2 and release CO2
- Blood goes back to the left side of the heart to start all over

Note: vessels going to the heart are veins; those leaving the heart are arteries
Composition of blood

- Specialized connective tissue
- Blood cells (formed elements) suspended in plasma

- Blood volume: 5-6 liters (approx 1.5 gal) in males and 4-5 liters in females
Blood

- Centrifuged (spun) to separate
- Clinically important **hematocrit**
  - % of blood volume consisting of erythrocytes (red blood cells)
  - Male average 47; female average 42
- **Plasma** at top: water with many ions, molecules, and 3 types of important proteins:
  - **Albumin**
  - **Globulins**
  - **Fibrinogen**
- Serum
  - Blood that is allowed to stand clots
  - Clot is a tangle of the “formed elements” (some are not truly cells)
    - RBCs lack nuclei and organelles
    - Platelets are fragments
    - Most cannot divide
  - Clear fluid *serum* is left = plasma without the clotting factors

When spun in centrifuge, buffy coat lies between RBCs and plasma: of leukocytes (white blood cells) and platelets
- Blood is examined in a "smear"
- Smears are stained
Hematopoiesis

- Formation of blood cells
- Occurs mostly in red bone marrow
- All cells arise from same \textit{blood stem cell} (pluripotent hematopoietic stem cells)
- Recently some have been found in adults which are \textit{mesenchymal stem cells}, which can also form fat cells, osteoblasts, chondrocytes, fibroblasts and muscle cells
Blood stem cells divide into:

1. myeloid stem cells or
2. lymphoid stem cells

All except for lymphocytes arise from myeloid stem cells

All originate in the bone marrow

Not shown are mast cells, osteoclasts, dendritic cells
- As the cells divide they become “committed,” that is, they can only become one kind of cell

- Also called CFU’s (colony-forming units)

- Structural differentiation occurs
CBC is probably commonest test done ("complete blood count"—how much of each type of cell)

- Hemoglobin (gm/dl) usually 15
- Hematocrit (%)
- RBC count
- WBC in thousands/cumm
  - Differential if ordered: broken down to amount of each type WBC
- Platelet count in thousands/cumm
Erythrocytes

- Also called RBCs or red blood cells
- Biconcave discs and flexible
- Plasma membrane but no nuclei or organelles
- Packed with hemoglobin molecules
  - Oxygen carrying protein
  - 4 chains of amino acids, each with iron which is binding site for oxygen; CO2 carried also
- Young ones still containing ribosomes are called reticulocytes
- Live 100-120 days
Leukocytes

AKA WBCs: white blood cells
Leukocytes

AKA WBCs: white blood cells

Are complete cells

Function outside the blood

Note the size difference compared to erythrocytes
Leukocyte types

- Artificial division into granulocytes and agranulocytes
- Granulocytes: neutrophils, eosinophils, basophils (according to how stain)
  - Granules
  - Lobed nuclei
  - All are phagocytic
- Agranulocytes: lymphocytes, monocytes
All except for lymphocytes arise from myeloid stem cells
All originate in the bone marrow

Not shown are mast cells, osteoclasts, dendritic cells
Neutrophils

- 60% of all WBCs
- Nuclei of 2-6 lobes
- Other names:
  - Polymorphonuclear cells (PMNs, polys, segs)
  - Granules have enzymes
  - Can damage tissue if severe or prolonged
  - Pus
Eosinophils

- 1-4 % of leukocytes
- Bilobed
- Granules have digestive enzymes
- Role in ending allergic reactions and in fighting parasitic infections
Basophils

- Rarest WBC
- Bilobed nucleus
- Dark purple granules
- Later stages of reaction to allergies and parasitic infections
Lymphocytes*

- Most important WBC
- 20-45%
- Most are enmeshed in lymphoid connective tissue, e.g. lymph nodes, tonsils, spleen
Lymphocytes: nucleus occupies most of the cell volume

Response to antigens (foreign proteins or parts of cells) is specific

Two main types attack antigens in different ways
  - T cells
  - B cells
  - plus “natural killer cells”
T cells attack foreign cells directly

- Killer cells ("cytotoxic"), or CD8+ is a main type
B cells

- Differentiate into **plasma cells**
- Plasma cells secrete **antibodies**
- Antibodies flag cells for destruction by **macrophages** (see stem cell chart)
Monocytes*

- 4-8% of WBCs
- In connective tissue they transform into macrophages (phagocytic cells with pseudopods)
Platelets*

- Not cells
- Small fragments broken off from **megakaryocytes**
- Important in forming **clots** in damaged vessels
- AKA **thrombocytes**
Clots

Undesirable clots:
- Thrombus
- Embolus

Platelet and several RBCs trapped in a fibrin mesh
Significant young cells

- **Reticulocytes** (young erythrocytes): 1-2% of all RBCs
  - “retic count” helps determine if producing RBCs at accelerated rate (anemia, move to a high climate, etc.)

- **Bands** (young neutrophils): 1-2% of all WBCs
  - Increases with acute bacterial infections
Disorders of Erythrocytes

- Polycythemia: too many cells
- Anemia: not enough cells
- Sickle cell disease: genetic disease AR
  - 1/400 African Americans
  - Defect in hemoglobin
- Plus many others
Disorders of Leukocytes

- Leukemia: too many, abnormal, crowd out normal marrow
- Classified into
  - Lymphoblastic or myeloblastic
  - Acute or chronic

Disorders of Platelets

- Thrombocytopenia
  - Causes internal bleeding
  - Many causes
Laboratory

CBC: complete blood count (to review…)

- Hemoglobin (gm/dl)
- Hematocrit (%)
- RBC count
- WBC in thousands/cumm
  - Differential if ordered: broken down to amount of each type WBC
- Platelet count in thousands/cumm
Laboratory continued

Clotting: “coags”

- for preop evaluation (before surgery)
- to evaluate effectiveness of anticoagulant drugs, e.g. aspirin, heparin, coumadin

- Bleeding time
- PT - Protime
- PTT - Partial thromboplastin time
- INR

ESR – erythrocyte sedimentation rate

- Indicator of infection or inflammation
Blood Typing

ABO blood groups: A, B, AB, and O
If a blood transfusion is given to a person who has antibodies to that type of blood, then the transfused blood will be attacked and destroyed (transfusion reaction)
## ABO blood group types

The blood types are “codominant” – i.e. if genotype is AB, then you have both A and B antigens on your RBCs.

<table>
<thead>
<tr>
<th>Blood type</th>
<th>Antigen on rbc</th>
<th>Antibodies in blood</th>
<th>Can receive blood from:</th>
<th>Can donate blood to (usually RBCs only):</th>
<th>Frequency in US</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>anti-B</td>
<td>A</td>
<td>A</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>O</td>
<td>AB</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>not B (you have anti-B)</td>
<td>not AB (you have anti-B) *</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>anti-A</td>
<td>B</td>
<td>B</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>O (no Ags so you won’t reject)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>not A (you have anti-A)*</td>
<td>not AB (you have anti-A) *</td>
<td></td>
</tr>
<tr>
<td>AB</td>
<td>A and B</td>
<td>none to A or B</td>
<td>AB</td>
<td>AB is universal recipient</td>
<td>4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>A</td>
<td>AB is universal recipient</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>not A nor B</td>
<td>Anti-A and anti-B</td>
<td>not A (have anti-A)*</td>
<td>A</td>
<td>46%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>not B (have anti-B)*</td>
<td>B</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>not AB (have both antibodies)*</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>AB</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>O</td>
<td></td>
</tr>
</tbody>
</table>

Ag = antigen on red blood cell
* = transfusion reaction (hemolysis of new cells)
Rh factor

- The “Rh factor” is another major antigen on the RBC, called D – is autosomal recessive
  - DD and Dd: Rh+
  - dd: Rh-
- If mom is Rh- and baby is Rh+, then small amount of blood leaks into mom’s blood through placenta, and she makes antibodies to D antigen; first Rh- pregnancy usually ok, but not later Rh- ones (can be lethal to baby)
- If mom is Rh- then give “Rhogam” during pregnancy [(is anti- Rh(D): Rh(D) Ig (immunoglobulin)], an antibody which will destroy any of the baby’s RBCs which leak into mom’s blood during the pregnancy so she will not mount an immune response to the D antigen
- If father is Rh+: 
  - If DD then all pregnancies will be Rh+
  - If Dd then half of the pregnancies with this mom will be Rh- (no Rh incompatibility problems)
Rhogam (FYI)

- **Risks to the baby**
  - If the baby’s blood cells are attacked and depleted during pregnancy it can lead to anemia, jaundice, mental retardation and heart failure. It can even be fatal in utero or shortly after delivery. The condition is known as Hemolytic Disease of the Newborn. Luckily, appropriate treatment with Rhogam can almost completely eliminate the risk.

- **[edit] Rh Negative treatment with Rhogam**
  - Rhogam is a sterile solution that is injected intramuscularly. It is made from human plasma that contains anti-D. Most often Rhogam is given to women at 28 weeks of pregnancy. The Rh negative mother is most likely to be exposed to the baby’s blood in the last 3 months of pregnancy, so a second dose is often given within 72 hours of delivery if the baby is found to be Rh positive. A mother must also receive a dose after any invasive procedure such as amniocentesis or after an induced termination, miscarriage or ectopic pregnancy.

- **[edit] Side effects**
  - Side effects of Rhogam are mild and include soreness tenderness, warmth or a rash at the injection site. Other side effects can include:
    - Fever
    - Chills
    - Headache
    - Fatigue

## TABLE 20.4 Differences in Blood Group Distribution

<table>
<thead>
<tr>
<th>Population</th>
<th>O</th>
<th>A</th>
<th>B</th>
<th>AB</th>
<th>Rh+</th>
</tr>
</thead>
<tbody>
<tr>
<td>U. S. (average)</td>
<td>46</td>
<td>40</td>
<td>10</td>
<td>4</td>
<td>85</td>
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<tr>
<td>Caucasian</td>
<td>45</td>
<td>40</td>
<td>11</td>
<td>4</td>
<td>85</td>
</tr>
<tr>
<td>African-American</td>
<td>49</td>
<td>27</td>
<td>20</td>
<td>4</td>
<td>95</td>
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<tr>
<td>Chinese</td>
<td>42</td>
<td>27</td>
<td>25</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Japanese</td>
<td>31</td>
<td>39</td>
<td>21</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Korean</td>
<td>32</td>
<td>28</td>
<td>30</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>Filipino</td>
<td>44</td>
<td>22</td>
<td>29</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Hawaiian</td>
<td>46</td>
<td>46</td>
<td>5</td>
<td>3</td>
<td>100</td>
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<tr>
<td>Native North American</td>
<td>79</td>
<td>16</td>
<td>4</td>
<td>&lt;1</td>
<td>100</td>
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<tr>
<td>Native South American</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Australian Aborigines</td>
<td>44</td>
<td>56</td>
<td>0</td>
<td>0</td>
<td>100</td>
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</tbody>
</table>