Cardiovascular System

• Internal transport network
• Links all body parts
• Embryos need by end of 3 weeks
  – Only a few mm long
  – Use diffusion until then
• First system to fully develop
Blood Functions

- “River of life”
- 1) Transports substances
  - Gases
  - Nutrients
  - Wastes
  - Hormones
- 2) Regulation of pH and ion composition
Blood Functions

- 3) Restricts fluid loss at injury sites
  - Blood clotting
- 4) Defense
  - Fights toxins and pathogens
- 5) Maintain body temp
Characteristics of Blood

• *Always* red
• 5x more viscous than water
  – Sticky
• Slightly alkaline
  – pH is 7.35 - 7.45
    • 7.4 = average
• Slightly warmer than body temp
  – 100.4°F (38°C)
• Metallic taste
Blood Collection

- **Venipuncture** – Using superficial vein to collect blood

- Why vein vs artery?
  - Easy to locate
  - Thinner walls
  - Lower bp
  - Puncture seals quickly
Blood Collection

- **Capillary blood** - used for a smear
  - Finger tip
  - Ear lobe (babies)
  - Big toe, heel
- **Arterial puncture** – used to evaluate gas exchange
Composition of Blood

• Connective tissue
  – The **ONLY** fluid tissue

• Living cells
  – Formed elements

• Nonliving fluid matrix
  – Plasma
Hematocrit (HCT)

- Percentage of whole blood sample that is occupied by cellular elements
- Measured after spinning in centrifuge
- Males ~ 46%
- Females ~42%
- Mostly RBCs
- Ratio of RBC to WBC – 1000:1
Centrifuging the Blood
Centrifuged Blood Sample

• **Plasma**
  – 46-63% (~55%)

• **Formed elements**
  – 37-54% (~45%)
  – Reddish
  – Mostly RBCs
Blood volume

• Men
  – 5.3-6.4 quarts (~1.5 gallons)
  – (5-6 liters)

• Women
  – 4.2-5.3 quarts (~.875 gallons)
  – (4-5 liters)

• Varies with:
  – Body size
  – Concentration of fluid and electrolytes
Plasma

- **Plasma**
  - Liquid part of blood
    - Called *serum* when proteins are removed
  - Straw colored
  - 92% water
  - Cells and platelets suspended
  - Dissolved in plasma
    - Nutrients
    - Ions
    - Gases
    - Hormones
    - Proteins
    - Wastes
Plasma

• **Plasma proteins**
  – Most abundant solute
  – Not usually used for energy
  – 3 main types:
    • 1) Albumins
    • 2) Globulins
    • 3) Fibrinogens
1) Albumins

- Smallest
- 60% of proteins
- Synthesized in liver
- Important determinant of osmotic pressure of plasma
  - Tends to hold water in capillaries
  - Help control blood pressure
2) Globulins

- 35% of proteins
- Include:
  - 1) **Antibodies** (Immunoglobulins)
    - Attack foreign proteins and pathogens
    - Made by plasma cells of lymphatic tissues
  - 2) **Transport Proteins**
    - Made in liver
    - Transports lipids, fat-soluble vitamins, and hormones
3) Fibrinogen

- 5%
- Blood coagulation (Clotting)
- Made in liver
- Largest of proteins
- Can interact and form fibrin (larger, insoluble)
Gases and Nutrients of Plasma

• Important gases:
  – Carbon dioxide
  – Oxygen

• Plasma nutrients:
  – Amino acids
  – Sugars
  – Nucleotides
  – Lipids
Plasma

• Transports glucose from small intestine to liver
  – Stored as glycogen OR converted to fat
  – Glycogen converted to glucose if blood glucose drops below normal

• Transports amino acids to liver
  - make proteins
  - used as energy
Plasma Lipids (p. 384)

• 3 Types:
  – Triglycerides (fats)
  – Phospholipids (fatty acids)
  – Cholesterol

• Lipids not soluble in water
  – Plasma = 92% water
  – Combine with proteins to make lipoproteins
Lipoproteins

• Less dense than pure proteins
• As % of lipids increases, density of lipoprotein decreases and vice versa
Types of Lipoproteins
(Chapter 17)

• Very low-density lipoproteins (VLDL)
  – high conc. of triglycerides
  – Bad

• Low-density lipoproteins (LDL)
  – high conc. of cholesterol
  – Major cholesterol carriers
  – Bad

• High-density lipoproteins (HDL)
  – high conc. of protein, low conc. of lipids
  – Good!

• Chylomicrons
  – triglycerides absorbed from small intestine
11.3 Erythrocytes (RBCs)

- **Erythros** = red
- Biconcave
  - Large surface area
  - Flex and squeeze thru capillaries
- Lack nucleus, mitochondria, and ribosomes when mature
  - Cannot make proteins
  - Cannot divide
  - Cannot “steal” Oxygen for cell. respiration
Erythrocytes

• ~ 260 million in 1 drop of blood
• Most numerous cells in body
  – ~ 25 trillion!
• Circulate ~120 days
• Recycled in liver, spleen, and bone marrow by macrophages
• Continually replaced
  – ~1% replaced each day
  – ~ 3 million new RBCs made each second!
Erythrocytes

- Contain hemoglobin (Hb)
  - Contains Iron
  - Transports O$_2$
Carrying Oxygen

• **Oxyhemoglobin**
  – oxygen attached to Hb combined
  – **bright red**

• **Deoxyhemoglobin**
  - No oxygen attached to Hb
  - **Dark red/burgundy**
Just because it’s interesting . . .

• ~250 million Hb molecules per RBC
  – Each Hb can bind 4 oxygen molecules
    • Each RBC can carry ~ 1 billion oxygen molecules
      – One drop of blood contains ~ 260,000,000,000,000,000,000 molecules of O₂

• Now that’s a lot of oxygen!
RBC Count

- Cells per cubic mm (microliter = µL)
  - Males ~ 5.4 million
  - Females ~ 4.8 million
Anemia

• Reduced oxygen-carrying ability
  – Lower numbers of RBCs (low HCT)
  – Less Hb

• Symptoms
  – Weakness
  – Muscle fatigue
  – Lack of energy
Hemoglobinuria

• Large numbers of RBCs break down
• Urine turns reddish or brown
  – Could be caused by a kidney infection
RBC Destruction

• After about 120 days:
• Macrophages in spleen, liver, red bone marrow
  – Break down RBCs
  – Hb freed and broken down into:
    • 1) **Heme** = iron-containing portion
      – Broken down into iron and **biliverden** (greenish pigment)
      – Iron is stored and/or reused
      – Biliverden converted to **bilirubin** (orange pigment)
        » Both pigments excreted in bile
        » Causes yellow color of urine and brown color of feces
    • 2) **Globin** = protein
Jaundice

• Caused by blocked bile ducts
  – Bilirubin diffuses into peripheral tissues
    • Causes skin and sclera to appear yellow
RBC Breakdown

• **Hemolyze** – to rupture
  – 10% of RBCs in blood stream rupture
    • All others engulfed by macrophages and recycled

• **Hemolysis** – breakdown of RBCs
Formation of Blood Cells

- **Hemocytoblast**
  - Stem cell
  - Found in red bone marrow
  - Each type of blood cell develops differently
Hematopoiesis

- Also called Hemopoiesis
- Formation of Blood Cells
- Erythropoiesis - formation of RBCs

- Adults:
  - Occurs in red bone marrow (myeloid tissue)
    - Vertebrae, sternum, ribs, scapulae, pelvis, proximal limb bones
  - Rarely occurs in yellow bone marrow
    - Ex: sustained blood loss

- Fetus:
  - Occurs in: yolk sac, liver, spleen, thymus, bone marrow
Blood Cell Formation
RBC Regulation

- Controlled by **Erythropoietin** (EPO)
  - (Erythropoiesis-stimulating hormone)
  - Liver makes some
  - Kidneys play major role in production
  - Targets bone marrow
  - Can increase RBC formation 10x (~30 million per second)
  - Diagram p. 390
RBC Regulation

• Controlled by blood oxygen levels
  – If low, turns on production
    • = Negative feedback system
    • Ex:
      – Anemia
      – Blood flow declines to kidneys
      – Oxygen in air declines
        » Disease, altitude
      – Lung damage
11.4 Blood Transfusions

- Replace substantial blood loss
- Collect blood from donor
  - Mixed with anticoagulant
  - Refrigerated
  - Can be stored 35 days
- Given to recipient
- Must be matched by type
Blood Antigens

- (agglutinogens)
- Genetically determined protein
- Surface of RBCs
- Can NOT cross placenta
  - Too big
  - Mom and fetus can be different blood types
Blood Antibodies

• (agglutinins)
  – Carried in plasma
  – Proteins
  – Recognize foreign antigens
  – Tolerate only our own
Agglutination

- Clumping of RBCs
  - Mix different RBC antigens
  - Antibodies attach to the RBCs
  - RBCs burst
  - Clogs small vessels
    - Anxiety
    - Breathing difficulty
    - Facial flushing
    - Pain
    - Kidney failure
Human Blood Types

• Four blood types (phenotypes): A, B, AB, and O
• Blood type is controlled by three alleles
• O is recessive
• A and B are codominant
Who gives to who?

• IF antigen of one type reacts with antibody of same type
  – Causes clumping

• **Universal Recipient = Type AB**
  – Has Antigens A and B
  – No antibodies
  – Can **give to ONLY AB** blood type
  – Can **receive ANY** blood type
Who gives to who?

• **Universal Donor =**
  
  Type O
  
  – No antigen A or B
  
  – Has Antibodies A and B
  
  – Can **give to ANY** blood type
  
  – Can **ONLY receive** type O
Blood Types p. 392
Rh Factor

• Named after Rhesus monkey
• Several factors (antigens)
  – Most common = antigen D
• Inherited trait
• Different from Blood type antigens
  – Smaller
    • Can cross from mother to fetus through placenta
• Do NOT appear spontaneously
  – Have to be stimulated
Rh Factor

- If any antigen present on RBC = **Rh-Positive**
- No Rh antigens = **Rh-Negative**
  - Only 15% of people in U.S.
Rh Factor Stimulation

• Example 1: Rh-negative person receives Rh-positive blood, then antibodies are produced. No reaction first time. If Rh-negative person is given Rh-positive blood again months later, reaction will occur.
Rh Factor Stimulation

• **Example 2:** If Rh-negative mother is pregnant with Rh-positive fetus for first time, no problem. However, cells from Rh-positive fetus #1 entered mom’s bloodstream causing antibodies to form that fight Rh-positive blood cells. Now, if another Rh-positive fetus begins to form, mother’s antibodies will attack fetal RBCs.
Human Blood Types
11.5 Leukocytes (WBCs)

- Fewer
- Larger
- Have nucleus and other organelles
- Protect against disease
- <1% of blood
- Can move in and out of blood vessels (*diapedesis*)
  - Squeeze through epithelial cells in capillaries
- 5 types normally in blood
Leukocytes

• Destroy invaders
• Move to areas of damage and infection
  – Use *ameboid motion* once outside of blood (interstitial spaces)
• Produce proteins (antibodies) that destroy invaders
WBC Count (WBCC)

- 6,000 – 9,000 per mm$^3$
- Increase = likely infection
- **Leukocytosis**
  - Higher than normal WBCC
    - acute infection >10,000 per mm$^3$
    - Ex: appendicitis, leukemia
- **Leukopenia** = <5,000 per mm$^3$
  - “penia” = poverty
  - Lower than normal WBCC
  - Ex: Flu, AIDS, Polio
WBCC

- **Leukemia** - “White blood”
  - Cancer
  - Some can be treated
  - If not treated, 100% fatal
  - May be caused by:
    - Extreme leukocytosis
      - >100,000 per mm$^3$
    - Large # of abnormal or immature WBCs
Classification of Leukocytes

• 5 main types (See chart p. 397)
• Two major groups based on presence of granules
  • A) Granulocytes
  • B) Agranulocytes
A) Granulocytes

- About 2x size of RBC
- Contain granules
  - Abundant secretory vesicles and lysosomes
- Lobed nuclei
- Develop in red bone marrow
- Short life span (~12 hours)
- 3 Types:
  - 1) Neutrophils
  - 2) Eosinophils
  - 3) Basophils
1) Neutrophils

- Stain light purple/pink
- Multi-lobed nucleus
  - Most = 2–5 lobes
  - Stain deep purple
- Most abundant
  - 54-62% of WBCs
- Phagocytizes small particles
- Fight acute infections
- Live about 10 hours
- **Pus** – mix of dead neutrophils, cellular debris, and other waste
2) Eosinophils

- Stain deep red
- Cytoplasm stains pink
- Bilobed nucleus
- Not abundant
  - 2-4% of WBCs
- Weakly phagocytic
- Increase:
  - Certain parasite infections
  - Allergic rx
3) Basophils

- Contain large **granules**
  - Stain deep blue or purple
  - Some contain **heparin**
    - Prevents blood clots
  - Some contain **histamine**
    - Increase blood flow to tissue
    - Helps with allergic response
- Bilobed nucleus
- Rarest
  - < 1% of WBC
B) Agranulocytes

- Granules very tiny
  - Don’t see easily
- More normal nuclei
- 2 Types:
  - 1) Monocytes
  - 2) Lymphocytes
1) Monocytes

- Largest WBC
  - 2x bigger than RBC
- Large nucleus
  - Often kidney-shaped or oval
  - 2-8% of WBC
- Circulate in blood stream for ~ 24 hrs
  - Then enter peripheral tissues and become macrophages
- Aggressive Phagocytes
  - “Clean up” team
  - Engulf large things
2) Lymphocytes

• Smallest
  – Slightly larger than RBC

• Large, round nucleus
  – Stains purple
  – Small rim of cytoplasm

• 20-30% of WBCs

• Found in lymphatic tissue

• Immune response
  – Produce antibodies

• Live for many years
11.6 Platelets

- No nucleus
- Cytoplasmic fragment
  - \( \frac{1}{2} \) size of RBC
- Arise from megakaryocytes – large cells in red bone marrow
  - (Megakaryocytes develop from hemocytoblasts)
- Circulate for 9-12 days
- Platelet count 150,000 to 500,000 per mm\(^3\)
  - Ave = 350,000
- Close breaks in blood vessels
  - Initiate blood clot formation
- **Thrombocytes** – platelets in nonmammals
  - Nucleated
About 400x
Abnormal Platelet Counts

• Thrombocytopenia – low count
  – <80,000 per mm$^3$
  – Bleeding in digestive tract, within skin, in CNS

• Thrombocytosis – high count
  – >1,000,000 per mm$^3$
  – Develops in response to cancer, infection, or inflammation
Formation of blood cells and platelets
11.7 Hemostasis

- Stoppage of blood flow
- Hem = “blood”
- Stasis = “standing still”
- Fast and localized
- Starts *clotting cascade*
  - Chain rx of events
- Three major phases:
  - 1) Vascular spasms
  - 2) Platelet plug formation
  - 3) Coagulation
Hemostasis

• Takes 3-6 minutes
• Rapidly inactivated after clot is made
  – Prevents widespread clotting
• Limited to blood that is standing still or moving slowly
Hemostasis

• 1) Vascular spasms
  – Last ~ 30 min
  – Platelets anchored
    • Release serotonin
      – Contracts smooth muscles in walls
      – Narrows blood vessel diameter
  – Decreases blood loss
  – Endothelial cells become sticky
    • Small capillaries may stick together
Hemostasis

• **2) Platelet phase**
  – Begins ~15 seconds after injury
  – Endothelium is normally smooth
    • Now broken = rough
  – **Platelet plug** formed
    • Platelets adhere to
      – Broken vessel
      – Each other
      – Collagen
    • Platelets pile up, form plug
Hemostasis

• 3) Coagulation events
  – Starts 30 seconds or more after injury
  – Injured tissues release **thromboplastin**
    • Activates **clotting cascade**
      – Prothrombin forms thrombin
      – Thrombin joins fibrinogen into fibrin
  – Fibrin traps RBCs
    • Forms clot
Undesirable Clotting

• **Causes:**
  – Physical blows
  – Fatty material build up
  – Slow flowing blood
  – Blood pooling
    • Immobilized patients
    • Anticoagulant use
  – * Roughed up endothelium causes platelets to cling
Thrombus

- Undesirable clotting
- Does not move
- In unbroken vessels
- May prevent blood flow
- Kills tissues supplied by vessel (infarction)
- May be fatal
- Coronary thrombus = Heart attack
Embolus

- **Undesirable clotting**
- Thrombus *floating freely* in vessels
- May get lodged in smaller vessel:
  - If lodged in artery
    - Can lead to cerebral embolus = stroke
  - If lodged in veins
    - Can get lodged in lungs = pulmonary embolism
Thrombus and Embolus
**Bleeding Disorders**

- **Liver:**
  - Synthesizes clotting factors
  - If liver cannot make clotting factors = abnormal and severe bleeding episodes
    - Vitamin K deficiency
      - Needed by liver to make factors
      - Easily corrected
    - Liver malfunction
      - Hepatitis or cirrhosis
      - Need transfusion
Bleeding Disorders

- **Hemophilia**
  - Hereditary
  - Clotting factors inadequate
  - “Bleeders disease”
    - Prolonged bleeding
    - Life threatening
    - Bleeding in joints
      - Disabled
      - Painful
  - Treatment
    - Transfusions
    - Injections of factors