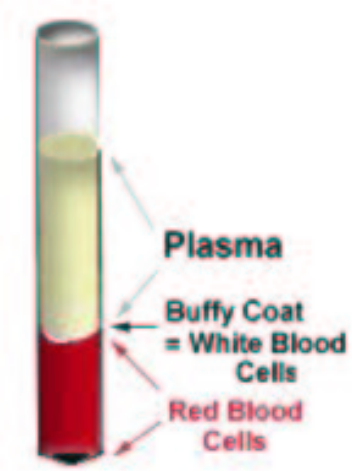
Blood
ANS 215
Physiology and Anatomy of Domesticated Animals

I. Introduction

A. Evolved to provide for the transport of nutrients to cells and waste from cells.
B. Additional functions relating to its role in maintaining fluid balance, pH equilibrium, and immune function.
C. Also developed means to prevent blood loss

II. Composition of Blood

A. Composed of cells and plasma
B. Cells of blood are:
    1. Erythrocytes
    2. Leukocytes
    3. Platelets



III. General Characteristics and Their Determination

A. Hematocrit
    1. Relative proportion of cells to plasma after centrifugation.
    2. Blood components are divided by their relative specific gravity
        a. erythrocyte mass = packed cell volume (PCV)
        b. buffy coat = leukocytes and platelets
        c. plasma = top portion
B. Blood color
    1. Red color imparted by hemoglobin within erythrocytes
    2. Degree of saturation of hemoglobin with oxygen determines gradations from bright red to bluish-purple
    3. Plasma is yellow to colorless depending on quantity and species
    4. Color of plasma results principally from bilirubin, a degradation product of hemoglobin

C. Blood Volume
    1. Function of the lean body weight and is generally 8 – 10% of body weight
    2. Ratio of the plasma volume (PV) to the blood volume is the same as hematocrit ratio
        a. PV/BV = 1 – PCV/1
        b. e.g. 1000kg cow has blood volume of 8% of body weight or 80L. If the hematocrit shows 60% is plasma then the plasma volume should be 48kg or 48L.

D. Blood pH
    1. Blood has a pH of about 7.4
    2. Venous blood is slightly more acidic than arterial blood
        a. Higher CO_2 in venous blood
    3. The pH symbol is the chemical notation for the logarithm of the reciprocal of the hydrogen ion concentration (H^+) in gram atoms per liter of solution.

IV. Leukocytes

A. Classified as either granulocytes or agranulocytes
    1. Three types of granulocytes based on uptake of stain
        a. neutrophils – take up red and blue dye
        b. basophils – take up blue dye
        c. eosinophils – take up red dye
    2. There are two types of agranulocytes
        a. monocytes
        b. lymphocytes

B. Granulocytes and monocytes are produced in bone marrow from myeloblasts.

C. Lymphocytes originate in a lymphoid cell in lymph tissue.

D. After their development, leukocytes circulate in blood until they leave the circulation to perform their extravascular function.

E. Generally, there are more erythrocytes than leukocytes in blood.

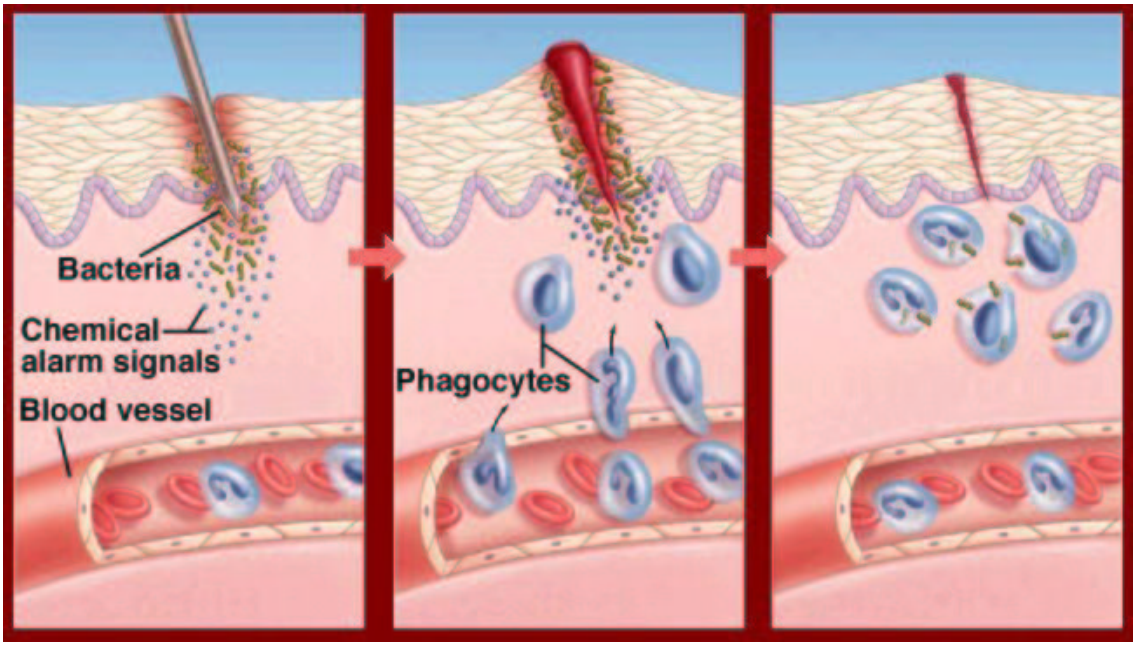
Total Leukocytes per Microliter of Blood and Percentage of Each Leukocyte

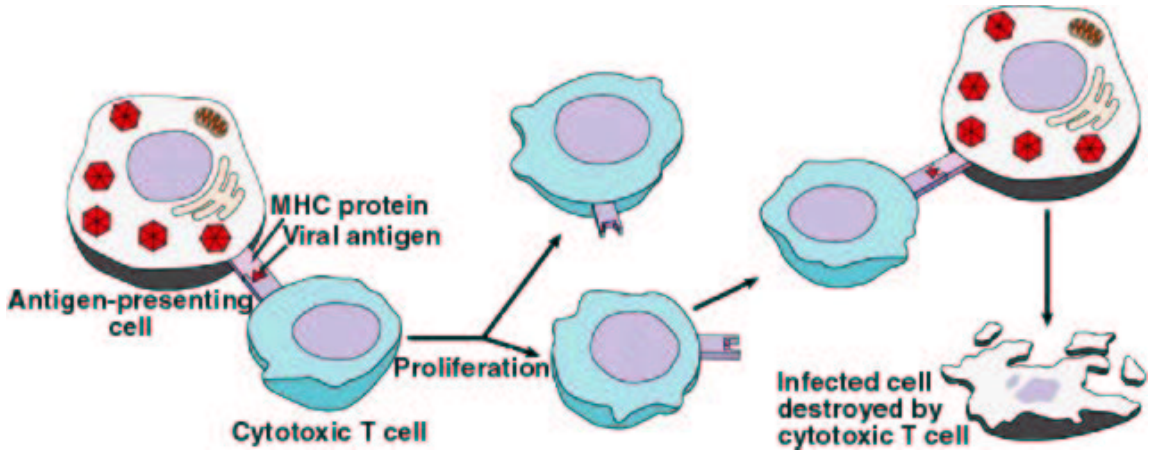
Species	Total Leukocyte Count (Range; no./µl)	Percentage of Each Leukocyte				
		Neutrophil	Lymphocyte	Monocyte	Eosinophil	Basophil
Pig						
1 day	**10,000-12,000**	**70**	**20**	**5-6**	**2-5**	**<1**
1 week	**10,000-12,000**	**50**	**40**	**5-6**	**2-5**	**<1**
2 weeks	**10,000-12,000**	**40**	**50**	**5-6**	**2-5**	**<1**
6 weeks +	**15,000-22,000**	**30-35**	**55-60**	**5-6**	**2-5**	**<1**
Horse	**8,000-11,000**	**50-60**	**30-40**	**5-6**	**2-5**	**<1**
Cow	**7,000-10,000**	**25-30**	**60-65**	**5**	**2-5**	**<1**
Sheep	**7,000-10,000**	**25-30**	**60-65**	**5**	**2-5**	**<1**
Goat	**8,000-12,000**	**35-40**	**50-55**	**5**	**2-5**	**<1**
Dog	**9,000-13000**	**65-70**	**20-25**	**5**	**2-5**	**<1**
Cat	**10,000-15,000**	**55-60**	**30-35**	**5**	**2-5**	**<1**
Chicken	**20,000-30,000**	**25-30**	**55-60**	**10**	**3-8**	**1-4**

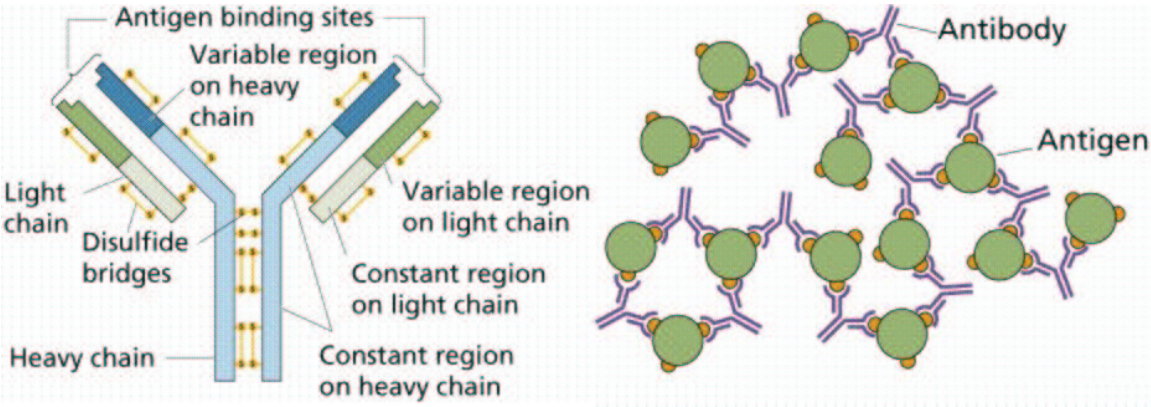
F. Function
    1. Neutrophils – amoeboid phagocytes

2. Monocytes – largest leukocyte, macrophage, numbers increase in chronic infection.
    a. some monocytes fixed in tissues, others migrate
3. Eosinophils – dampen inflammatory reactions – increase during certain types of parasitism, are reduced during stress by cortisol, increase in eosinophils can also indicate allergic response
4. Basophils – enhance inflammatory reaction in response to IgE
5. Lymphocytes – involved in immune response
    a. T-cells – preprocessed in thymus
        i. cytotoxic T-cells – killer cells
        ii. helper T-cells – assist in activation of killer cells, suppressor T-cells and B-cells
        iii. suppressor T-cells – suppress action of cytotoxic and helper T-cells
    b. B-cells – preprocessed in bone marrow
        i. produce antibodies – humeral immunity
        ii. Antibodies inactivate antigens by agglutination and precipitation.
        iii. Antibodies are also involved in complement system in which antibodies bind to foreign cells which then attract phagocytes and killer cells.

G. Plasma cells and megakaryocytes
1. Plasma cells are found in lymphoid tissue and produce antibodies.
2. Megakaryocytes are found in bone marrow and give rise to blood platelets, which are involved in clotting.







V. Diagnostic Procedures

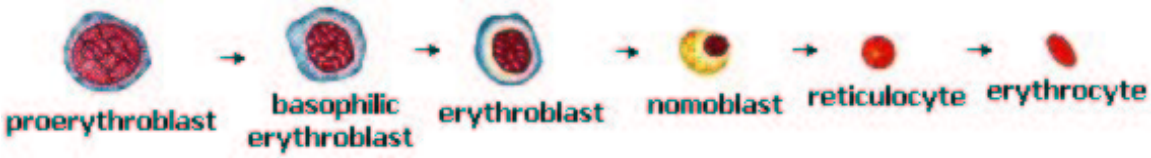
Average Values for Several Blood Variables

Variable	Animal					
	Horse	Cow	Sheep	Pig	Dog	Chicken
Total RBC/µl blood (x 10^6)	9.0	7.0	12.0	6.5	6.8	3.0
Diameter of RBC (µm)	5.5	5.9	4.8	6.0	7.0	elliptic 7 x 12
PCV (%)	41.0	35.0	35.0	42.0	45.0	30.0
Sedimentation rate (mm/min.)	2-12/10	0/60	0/60	1-14/60	6-10/60	1.5-4/60
Hemoglobin (g/dl)	14.4	11.0	11.5	13.0	15.0	9.0
Coagulation time (capillary tube method; min)	2-5	2-5	2-5	2-5	2-5	-
Specific gravity	1.060	1.043	1.042	1.060	1.059	1.050
Plasma protein (g/dl)	6-8	7-8.5	6-8	6.5-8.5	6-7.8	4.5
Blod pH (arterial)	7.40	7.38	7.48	7.4	7.36	7.48
Blood volume (% of body weight)	8-10	5-6	5-6	5-7	8-10	7-9
Mean corpuscular volume (MCV; fl)	45.5	52.0	34.0	63.0	70.0	115.0
Mean corpuscular hemoglobin (MCH; pg)	15.9	14.0	10.0	19.0	22.8	41.0

Mean corpuscular hemoglobin concentration (MCHC; %)	**35.0**	**33.0**	**32.5**	**32.0**	**34.0**	**29.0**

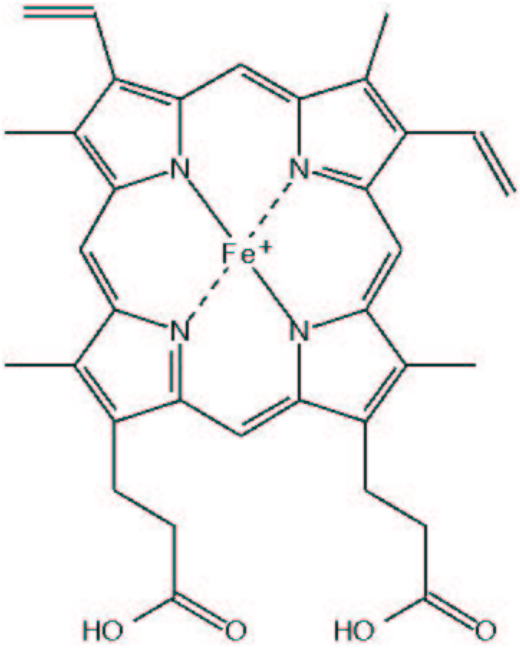
VI. Erythropoiesis

A. Production of red blood cells (RBC) – erythrocytes
B. Before birth, occurs in liver, spleen, and bone marrow
C. After birth – bone marrow
D. Axial and appendicular skeleton bone marrow accounts for 35% and 65% (respectively) of RBC production.

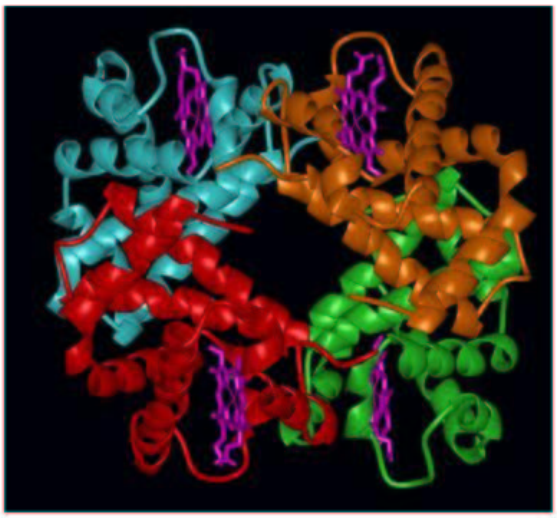


VII. Hemoglobin and its Forms

A. Principal component of erythrocytes is hemoglobin – 30% of content
B. Composed of 4 heme groups and 1molecule of globin
C. Each heme group contains an iron atom, which can bind with oxygen
D. Hemoglobin increases oxygen carrying capacity of blood 60-fold
E. Nitrate poisoning prevents oxygen from binding to hemoglobin
F. Carbon Monoxide also interferes with hemoglobin function
G. Hemoglobin in muscle is called myoglobin



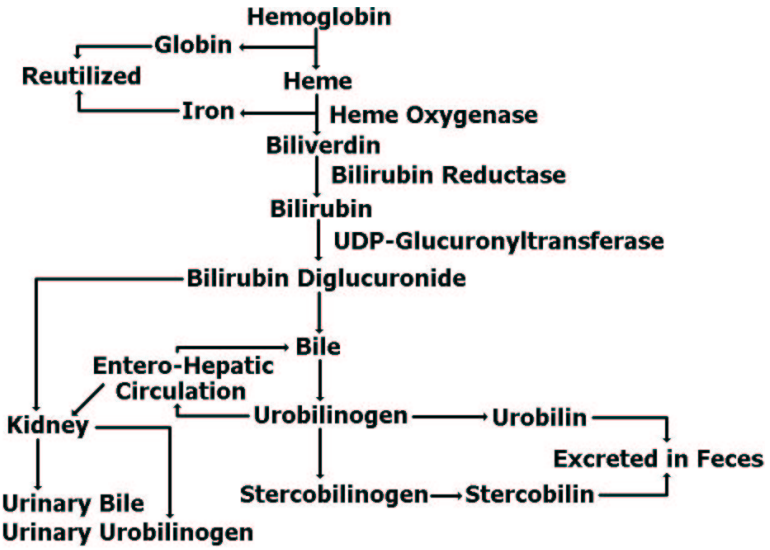
Heme



Hemoglobin

VIII. Red Cell Turnover

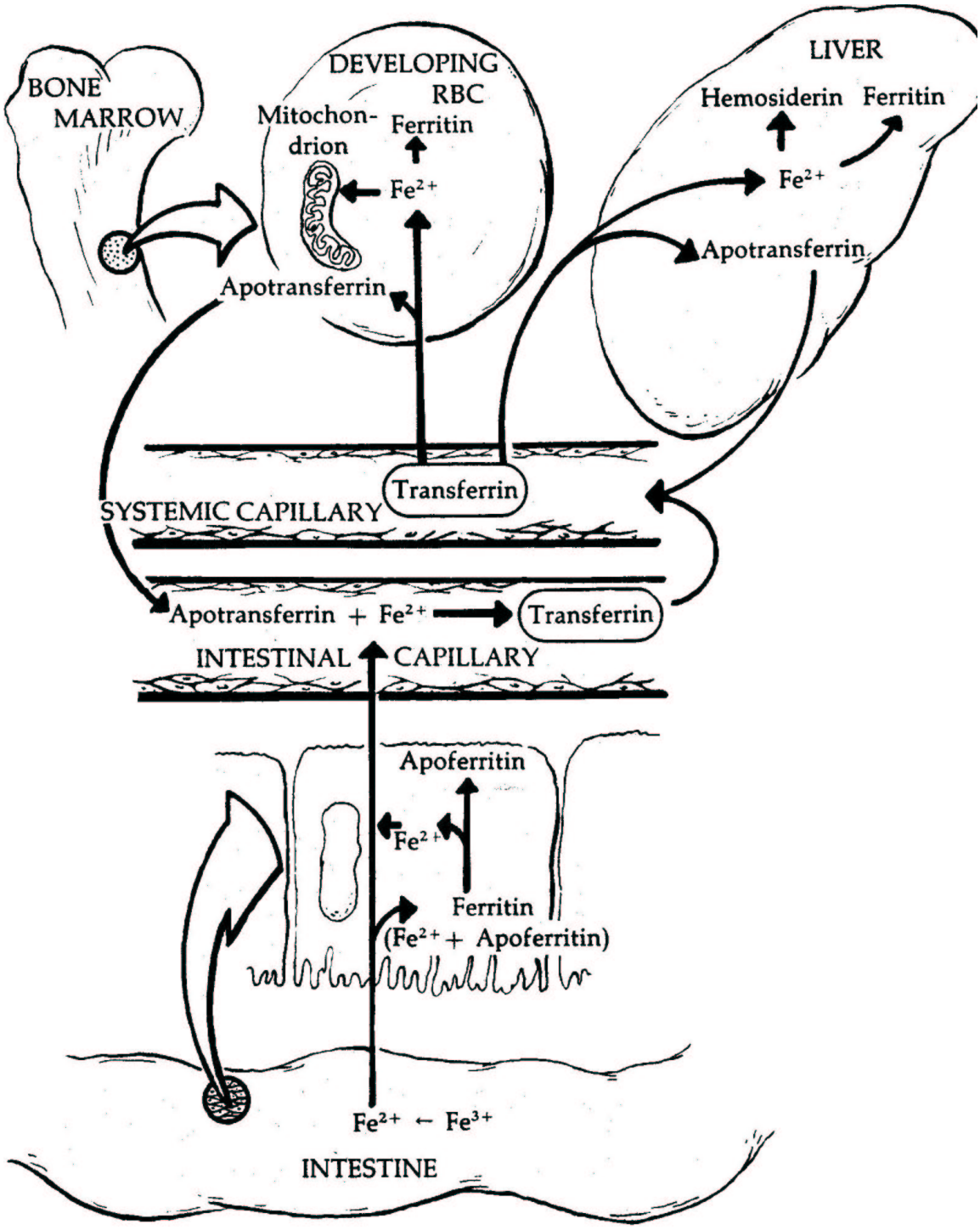
A. Some intravascular hemolysis of erythrocytes occurs (10%)
B. Remainder (90%) are removed by phagocytosis in the spleen, liver and bone marrow by fixed monocytes.
C. Hemoglobin is metabolized by phagocytes to bilirubin and is released into the plasma where it is bound to albumin and transported to the liver where it is converted to bilirubin diglucuronide and is secreted into bile and urine.
    1. In liver disease the bilirubin continues to circulate in plasma resulting in jaundice.
D. The iron is stored in the monocytes in the form of ferritin and hemosiderin or is transferred to plasma where it binds with apotransferrin. Transferrin circulates to the bone marrow where the iron is used to synthesize new hemoglobin.
E. The globin is broken down into amino acids and used by a variety of cells for protein synthesis.



Summary of hemoglobin degradation with its beginning in mononuclear phagocytic system cells. The line from bilirubin diglucuronide to the kidney is actually an insignificant or abnormal direction for its excretion.

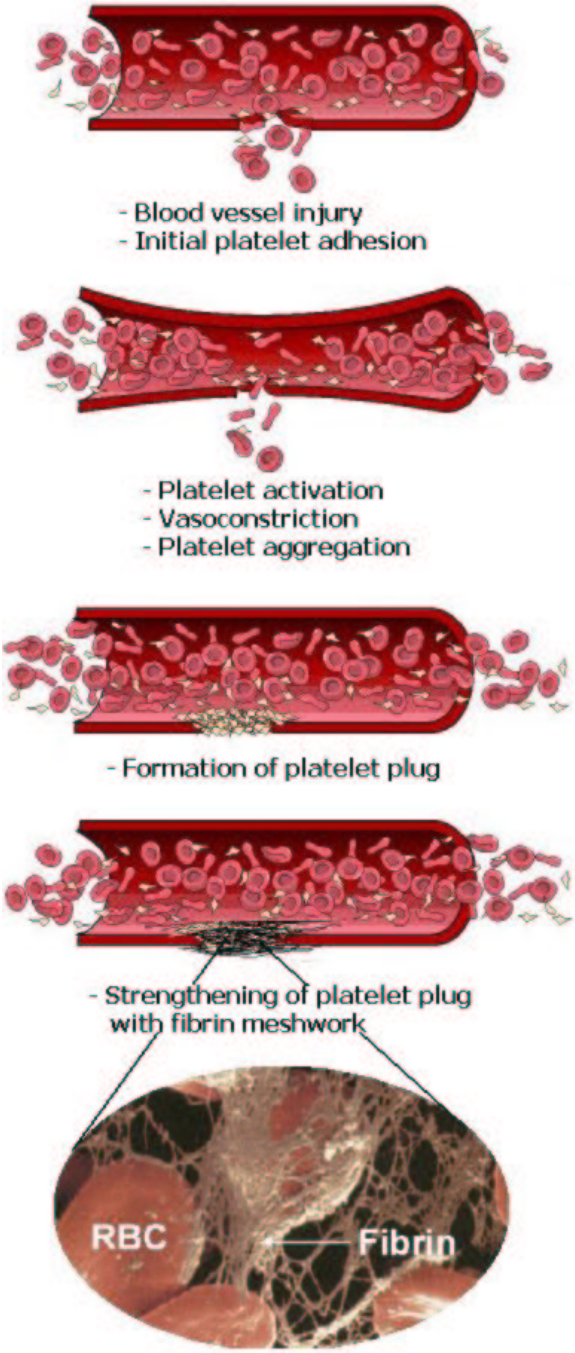
IX. Iron Metabolism

A. Large portion of ingested iron is reduced to ferrous iron (Fe^{2+}) in the stomach.
B. Absorbed from duodenum and jejunum by intestinal cells
C. From the intestinal cells it enters the blood and then binds with apoferritin to become ferritin, a storage form of iron.
D. Ferritin combines with apotransferrin in blood to become transferring.
E. In bone marrow, the developing erythrocytes have receptors for transferrin.
F. Transferrin is internalized into the developing erythrocyte and the iron is released where it is incorporated into hemoglobin in mitochondria.



G. Reduction in number of erythrocytes, concentration of hemoglobin, or both is called anemia.
   1. functional anemia – tissues do not become hypoxic because of lack of exertion or because of erythropoietin is not formed.
   2. iron-deficiency anemia – due to rapid growth and low iron content of diet
   3. aplastic anemia – poor erythrocyte production
   4. polycythemia – overproduction of red blood cells

X. Prevention of Blood Loss

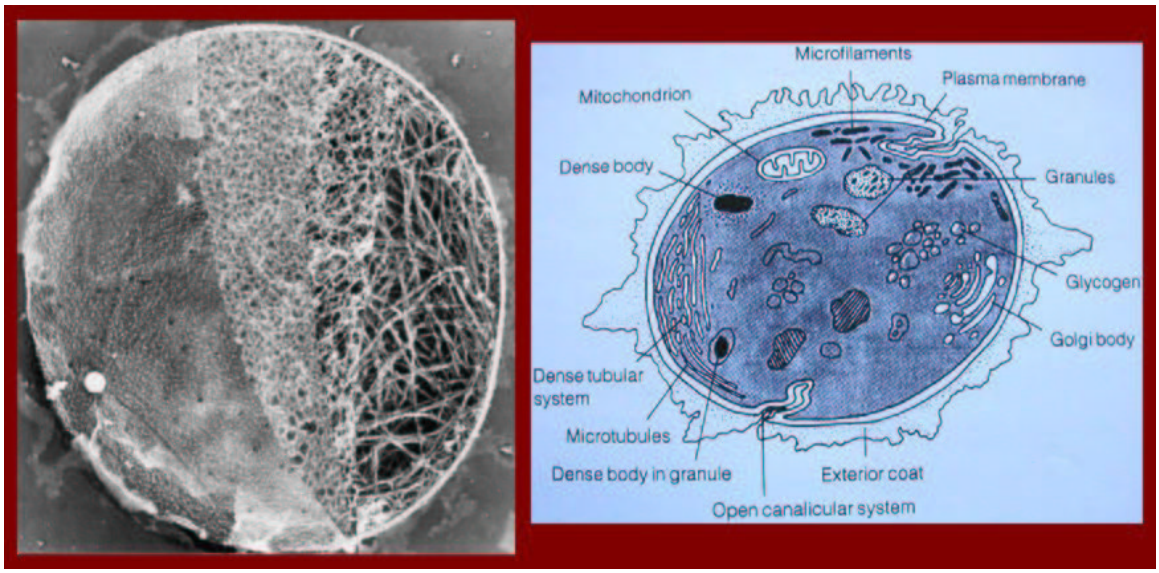


A. When a blood vessel is damaged, endothelial cells are separated, the underlying collagen is exposed, and the surface loses its smoothness.
B. Platelets begin to contact the damaged surface initiating the adhesion process.
C. Adhered platelets undergo a reaction releasing aggregating agents causing accumulation of more platelets.
D. A loose plug is formed that is strengthened with the formation of a fibrin meshwork.
E. The damaged vessel is then repaired by connective tissue and endothelial cell

growth.

F. The platelet-fibrin complex and cell debris is then removed by phagocytes.
G. Vascular endothelium lines the entire cardiovascular system.
    1. 1 cell layer thick
    2. Regardless of location it is underlaid by collagen
    3. Collagen is a potent platelet activator
    4. The subendothelial tissue also contains fibronectin and Von Willebrand factor, which both enhance aggregation of platelets.
H. Properties of endothelium that inhibit aggregation are:
    1. Negative charge on endothelium surface
    2. Synthesis of inhibitors of aggregation (e.g. prostacyclin) and fibrin formation (thrombomodulin)
    3. Generation of activators of fibrin degradation (e.g. tissue plasminogen activator, TPA)

XI. Platelets



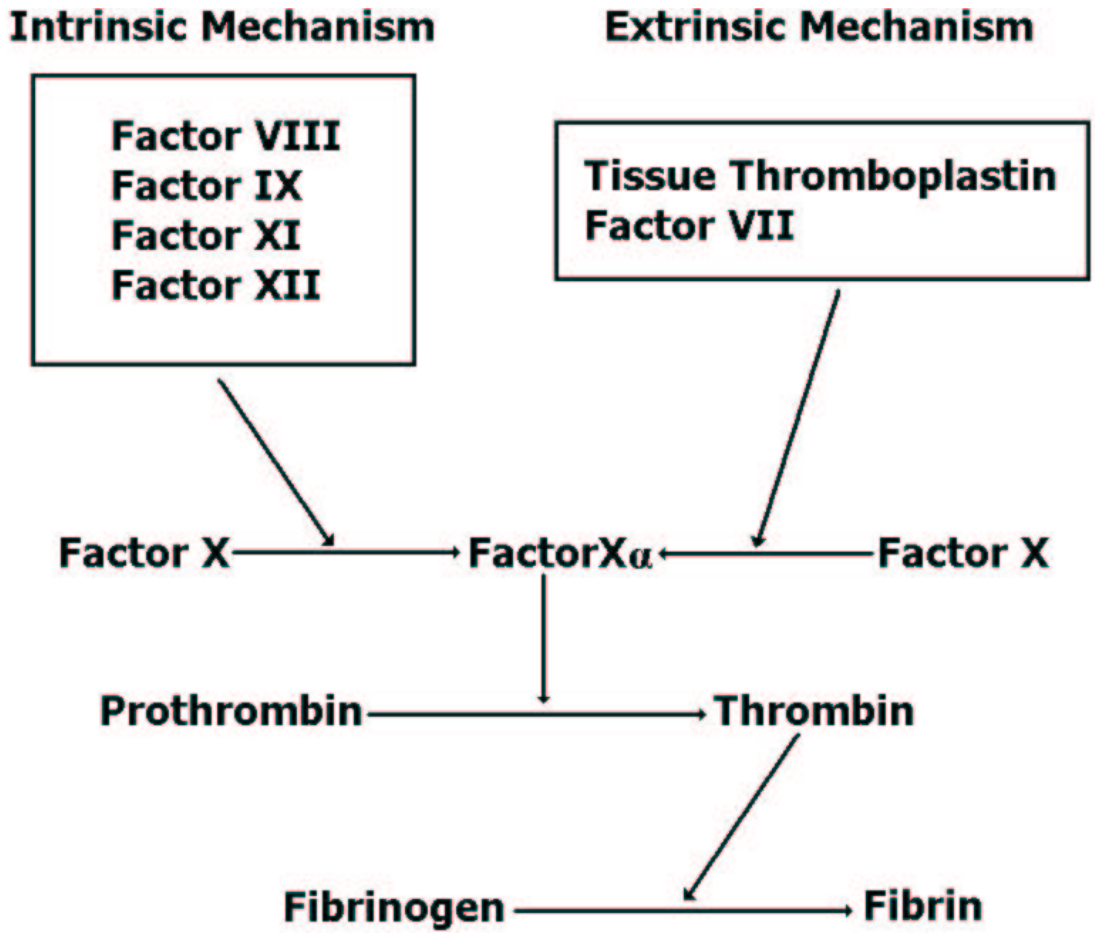
A. Platelets are also known as thrombocytes
B. Microtubules that encircle the platelet contract when activated, extruding platelet granule contents.
C. Release of granule contents requires energy from mitochondria.

Factor	Synonym	Site of synthesis
Fibrinogen	**Factor I**	**Liver**
Prothrombin	**Factor II**	**Liver**
Tissue factor	**Thromboplastin, factor III**	**Tissues**
Factor V	**Proaccelerin**	**Platelets**
Factor VII	**Proconvertin**	**Liver**
Factor VIII	**Factor VIII: C, antihemophilic factor**	**Vascular endothelium**
Factor IX	**Christmas factor**	**Liver**
Factor X	**Stuart factor**	**Liver**
Factor XI	**Plasma thromboplastin antecedent**	**Liver**
Factor XII	**Hageman factor**	**Liver**
Factor XIII	**Fibrin stabilizing factor**	**Liver**
von Willebrand factor	**VWF**	**Megakaryocytes, endothelial cells**
Prekallikrein	**Fletcher factor**	**Liver**
High-molecular-weight-kinogen	**HMWK**	**Liver**
Fibronectin	**Cold-insoluble globulin**	**Liver**

D. Factors present in blood assist in coagulation
    1. Adhesion – VWF and fibronectin
    2. Activation – inhibited by aspirin
    3. Aggregation – fibrinogen, fibronectin, VWF, Factor V
    4. Coagulation:
        a. intrinsic mechanism – contact of blood with foreign surface
            i. Factor VIII
            ii. Factor IX
            iii. Factor XI
            iv. Factor XII
        b. extrinsic mechanism – contact of blood with extravascular tissue
            i. Thromboplastin
            ii. Factor VII
    5. In typical injury, both mechanisms are involved

E. Prevention of coagulation in normal circulation
    1. Antithrombin III blocks the action of thrombin on fibrinogen and inactivates the thrombin it binds
    2. Smoothness of endothelium
    3. Monomolecular layer of protein absorbed to surface of endothelium repels clotting factors and platelets.
    4. Heparin produced by mast cells inhibits clotting.

F. Anticlotting agents tie up calcium-EDTA, citra



G. Tests for coagulation
   1. Used to determine adequacy of clotting in an animal
   2. Vitamin K deficiency results in hemorrhage, because of inadequate formation of prothrombin and factors VII, IX, and X.