Cardiovascular System: Blood

- Physical characteristics
- Overall Functions
- Components structure and function
  - Plasma
  - Formed elements (rbc, wbc, platelets)
- Hemostasis and blood clotting
- Blood groups and typing
- Capillary exchange and lymphatic capillaries
- Disorders of the blood discussed throughout

1

Physical Characteristics of Blood

- Specialized connective tissue
- Quantity
  - 5-6 liters (1.5 gallons) in adult men
  - 4-5 liters in adult women
  - ~8% of our body weight
- Thick and sticky
  - Denser and more viscous than water
- Opaque
- Bright red in color (oxygen rich) or dark purple (oxygen poor)
- pH= 7.35 to 7.45

2

Overall Functions of Blood

- Transportation of all substances needed by the body
  - O_2 from lungs
  - Nutrients from digestive tract
  - Hormones from endocrine glands
  - Delivers wastes to kidneys and lungs for excretion
- Regulation of
  - Body temperature
  - Volume of water in the body
  - pH of body fluids
- Defense
  - Protects against infection
  - Prevents blood loss by forming clots

These f(x)s are crucial for maintaining homeostasis

3

Overall Components of Blood

- Plasma is the liquid component (55%)
  - Nonliving liquid matrix
    - 90-92% is water
    - 7-8% is proteins
    - 1% other molecules
- Formed elements (45%)
  - Living cells and cell fragments
    - Red blood cells (rbc or erythrocyte)-99%
    - White blood cells (wbc or leukocytes) <1%
    - Platelets <1%

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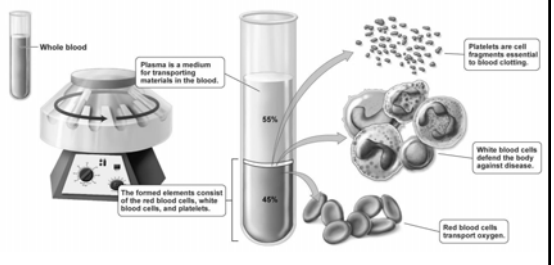
Separating Blood into its Major Components



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Components of Blood: Plasma

Liquid portion of blood that functions as transport medium for blood cells, platelets and other substances (pale yellow when separated)

Table 6.1 Blood Plasma Solutes

Plasma proteins	Albumin, globulins, ibrinogen
Inorganic ions (salts)	Na , Ca^2 , K , Mg^2 , Cl , HCO_3 , HPO_4^2 , SO_4^2
Gases	O_2, CO_2
Organic nutrients	Glucose, fats, phospholipids, amino acids, etc.
Nitrogenous waste products	Urea, ammonia, uric acid
Regulatory substances	Hormones, enzymes

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Plasma Proteins

- Albumins
  - ~2/3 plasma proteins
  - Maintain water balance
  - Manufactured in liver
  - Transport lipid soluble substances
    - Bilirubin, fatty acids, penicillin
- Globulins
  - Some are antibodies that protect against disease
  - Transport some lipids including fats and cholesterol (HDL, LDL), fat soluble vitamins
- Clotting proteins
  - Fibrinogen

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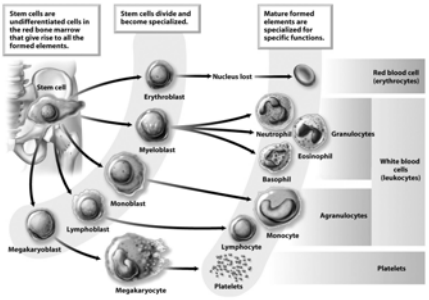
Stem Cells Give Rise to the Formed Elements



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Formed Elements: Red Blood Cells (RBCs)

- AKA Erythrocytes or red corpuscles
- 99% of formed elements and major cause of viscosity
- 4-6 million per mm^3 or one drop of blood
- 45% of total blood volume
- Structure
  - Small biconcave disks (flattened doughnut and sunken in middle)
  - Lack a nucleus when mature and have few organelles
  - Packed with hemoglobin (Hb)
- Function
  - Carry O_2 to all cells; carry away some CO_2 (~25%)
- FORM FITS FUNCTION
  - Bend and squeeze through capillaries
  - Shape maximizes surface area
  - Built to transport O_2

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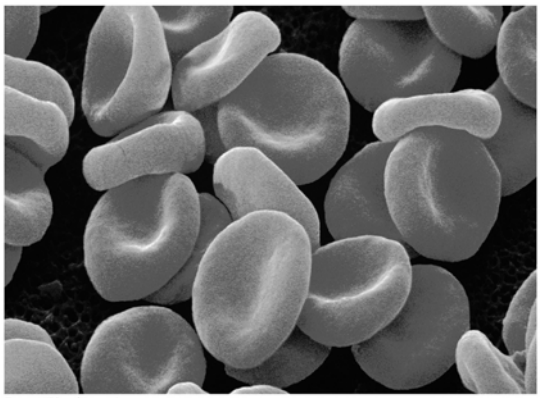

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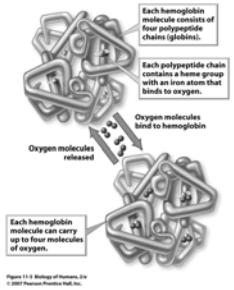
Hemoglobin (Hb)



- Consists of 4 polypeptide chains
  - Each with an iron-containing heme group that binds O_2
- Hb-O_2 called oxyhemoglobin and is bright red
- Hb without O_2 called deoxyHb and is dark purple
- >280 million Hb molecules in one RBC, 4 O_2 per Hb
- Functions best at about neutral pH and when O_2 concentration is high
- Binds with greater affinity (~200X) to carbon monoxide (CO), making Hb unavailable for O_2 transport
  - CO poisoning can be fatal

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Hematocrit: Percentage of RBCs in Blood

- Important measure of O_2 carrying capacity
- Normal range
  - 43-49% in men
  - 37-43% in women
- Low hematocrit
  - May signal anemia or other disorders of inadequate RBC production
- High hematocrit
  - Can thicken blood and increase risk of clots
  - Polycythemia - overproduction of RBC
- Some shifts normal and temporary
  - Increases when stay at high altitude
  - Returns to normal when you return to normal altitude
  - Example of homeostatic regulation of blood oxygen

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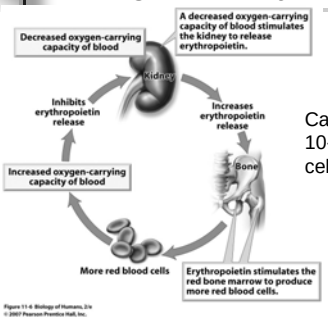
Lifecycle of a RBC

- Stem cell to mature RBC takes about a week
- Produced and destroyed at a rate of ~2 million/sec
- Life span around 120 days
  - ~3000 round trips a day
- Old and damaged RBCs are destroyed in liver and spleen by macrophages
  - Amino acid and iron parts are reused
  - Heme portion gets broken down by liver and converted to yellow pigment called bilirubin
    - Gets excreted with bile and contributes to color of feces and urine
  - Jaundice is accumulation of bilirubin in plasma
    - Yellowing of whites of eyes and skin
  - Breakdown of heme to bilirubin at site of a bruise contributes to yellowish tinge in skin

RBC Production is Regulated by a Hormone



Can increase production 10-fold to ~20 million cells/sec

Blood Doping

- Any method of increasing the number of RBC's to increase athletic performance
  - Epogen can be injected into a person months prior to an athletic event OR
  - Blood is drawn, stored, then returned to the body
- Increases O_2 carrying capacity of blood
- Makes blood more viscous and heart has to pump harder
  - After exercise dehydration can concentrate blood more
  - Increases risk of clots, high blood pressure, heart attack, stroke

Anemia

- General term for a decrease in the O_2 carrying capacity of blood
- Causes
  - Lower than normal number of RBC
  - Lower than normal hemoglobin content in RBC
- Symptoms include
  - Fatigue, pale skin, headaches, dizziness, difficulty breathing
- Iron, folic acid (B vitamin), and Vitamin B12 are necessary for production of RBCs
- Some women may become slightly anemic because of heavy menstrual flow

Types of Anemia

- Iron deficiency anemia - insufficient iron results in less Hb per RBC, most common form
- Folic acid anemia - folic acid deficiency
- Pernicious anemia - deficiency of B12 absorption by GI tract
- Aplastic anemia - bone marrow does not produce enough stem cells
- Hemorrhagic anemia caused by extreme blood loss
- Sickle-cell anemia - RBCs are sickle-shaped (abnormal Hb) when O_2 concentration is low
  - Shape makes it harder to travel through small vessels and encourages early destruction and clotting
- Hemolysis is the rupturing of RBC
  - Hemolytic disease of the newborn

Formed Elements: White blood cells (WBC)

- AKA leukocytes
- Functions
  - Defend the body against disease
  - Remove wastes, toxins, and damaged or abnormal cells
- Produced in bone marrow and arise from stem cells
- Make up less than 1% of formed elements AND we couldn't live without them
  - Only about 7000 per drop blood (5000-11,000)
- Five types of WBCs in two categories
  - Granular leukocytes or granulocytes
  - Agranular leukocytes or agranulocytes

Characteristics of WBC

- Larger than RBCs
- More diverse in structure and function
- Have a nucleus and organelles but no Hb
- Are translucent so need to be stained to be seen
- Most have life span even shorter than RBCs
  - Granular leukocytes live a few hours to 12 days
  - Agranular leukocytes live months to many years
- Liver and spleen destroy worn out WBC
- Not confined to bloodstream and can move to site of infection, inflammation, or tissue damage

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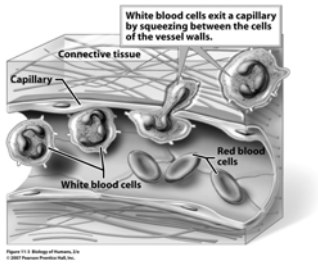
WBC Movement

- Capable of exiting and re-entering a blood vessel
- Move to the site of infection or tissue damage
- Amoeboid movement



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WBC: Granulocytes

- Neutrophils: stain neutral
  - Most abundant type (~60% of WBC)
  - Are the first to respond to an infection and engulf microorganisms by phagocytosis
- Eosinophils: stain red or pink
  - Defend against parasitic worms (tapeworms, hookworms, etc..) by surrounding and blasting them with digestive enzymes
  - Release chemicals that are involved in allergic reactions
    - Lessen their severity
- Basophils: stain blue
  - Most rare of WBC
  - Release histamines
    - Initiates inflammatory response
      - Attract other WBC to injured area
    - Associated with allergic reactions (dilate blood vessels and constrict air ways)

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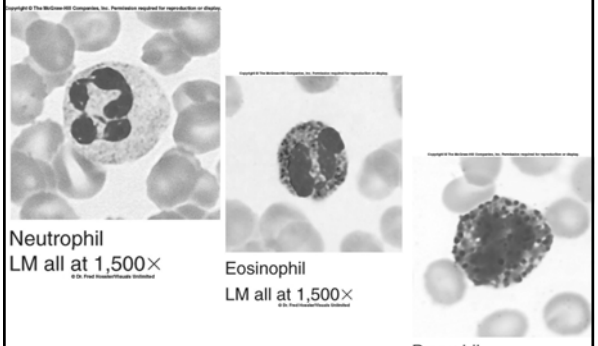

Neutrophil
LM all at 1,500×

Eosinophil
LM all at 1,500×

Basophil
LM all at 1,500×

22

WBC: Agranulocytes

- Monocytes
  - Are the largest of WBC and have U-shaped nuclei
  - Filter out of bloodstream and take up residence in body tissues
  - Become larger macrophages that phagocytize pathogens, old or abnormal cells, and cellular debris
  - Stimulate other WBC to defend the body
- Lymphocytes
  - Make up about 30% of WBC
  - Spherical nucleus that almost fills the cell
  - Two types
    - B lymphocytes - give rise to plasma cells that make antibodies
    - T lymphocytes - attack damaged or diseased cells

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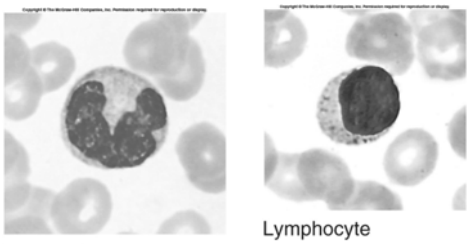

Monocyte
LM all at 1,500×

Lymphocyte
LM all at 1,500×

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Disorders of WBCs

- Leukocytosis - increase in number of WBCs
  - Normal when body is invaded by bacteria, viruses, or other foreign substances
  - Abnormal - infectious mononucleosis, leukemia
- Infectious mononucleosis – viral disease caused by Epstein-Barr virus (EBV)
  - Infects monocytes resulting in an increase and abnormal appearance
  - Symptoms include fatigue, sore throat, fever, chills, and swollen lymph nodes
- Leukemia – a groups of cancers of WBCs that results in their uncontrolled multiplication
- Leukopenia – decrease in number of WBCs
  - Can be caused by certain drugs, like chemotherapeutic agents

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Formed Elements: Platelets

- AKA thrombocytes
- Disk shaped cell fragments NOT actual cells
- Fragments are from precursor cells called megakaryocytes in the red bone marrow
- Produced at a rate of 200 billion per day
- 150,000 to 300,000 per mm^3 (drop of blood)
- Life span 5 to 10 days
- Important in the process of blood clotting or coagulation

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Hemostasis: Stopping Blood Loss

- Vessel damage occurs
- Vascular spasms, or intense contraction of blood vessels occur to reduce blood flow
- Formation of platelet plug - platelets swell and stick together to seal a ruptured vessel
  - Platelets produce a chemical that attracts more platelets
    - Aspirin prevents formation of this chemical
- Formation of a blood clot or coagulation - blood changes from liquid to gel
  - Prothrombin activator is released from damaged vessel, platelets, and surrounding tissues
  - A series of chemical reactions produces fibrin strands
  - Fibrin strands, blood cells, and platelets form a meshwork sealing the damaged vessel
  - Clot contracts and pulls damaged edges together, further sealing the opening

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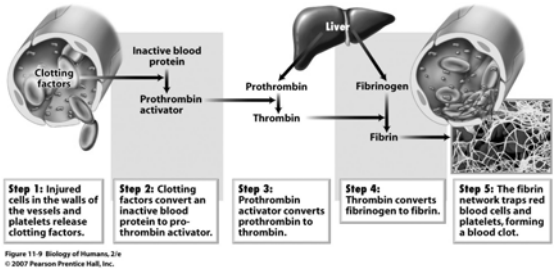

•When wound is healed, plasmin formed from plasminogen digests the fibrin strands of the clot

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Blood Clotting Disorders

- Even if one of the factors needed for clotting is lacking the process is slowed or blocked
  - Vitamin K and Ca^{+2} also necessary
- Thrombocytopenia – low platelet count that can result in the inability of blood to clot
  - Viral infections, anemia, leukemia, exposure to radiation,exposure to certain drugs…
- Thromboembolism – when a clot forms and breaks off from its site of origin and plugs another vessel
- Hemophilia – inherited clotting disorder due to a deficiency in one or more clotting factors
  - Treatment involves restoring missing clotting factors
  - Bleeding episodes controlled with transfusions

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Blood Loss and Blood Transfusion

- 15 – 30% blood loss
  - Pallor (pale skin color) and weakness
- Loss of 30% or more strains body's ability to maintain blood pressure and oxygenate tissues
  - Need blood transfusion – transfer of blood from one individual into another individual
  - Can lead to severe shock followed by death if not replaced
    - Shock is a state in which blood flow to the tissues of the body is inadequate to sustain life

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Donating Blood

- Donating blood is a safe and sterile procedure
- You will donate about a pint of blood
- You will replace the plasma in a few hours and the cells in a few weeks
- A few people may feel dizzy afterwards so sit down, eat a snack and drink some water
- Your blood will at least be tested for syphilis, HIV antibodies and hepatitis and if any of them come back positive you will be notified
- Your blood can help save many lives
- You should not give blood if:
  - You have ever had hepatitis, malaria or been treated for syphilis or gonorrhea within 12 months
  - If you are at risk for having HIV or have AIDS

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Blood Groups and Blood Types

- Human blood is classified into different **blood types**
  - Determined by the presence or absence of proteins on surface of RBCs
  - Named by the antigen found on the surface of the cell
    - ABO blood groups and Rh factors
- Some background and definitions
  - Antigen (generate against) - proteins in cell membranes that body recognizes as self
  - Antibodies (against the body) - proteins that mount attack against foreign cells or antigens
  - Agglutination - clumping
  - Transfusion reaction - any adverse effect of a blood transfusion

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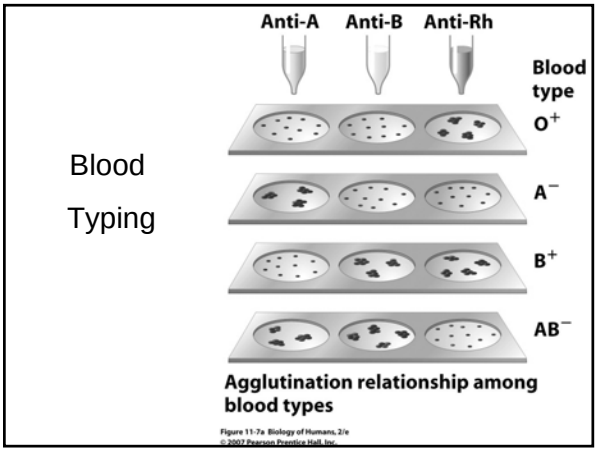
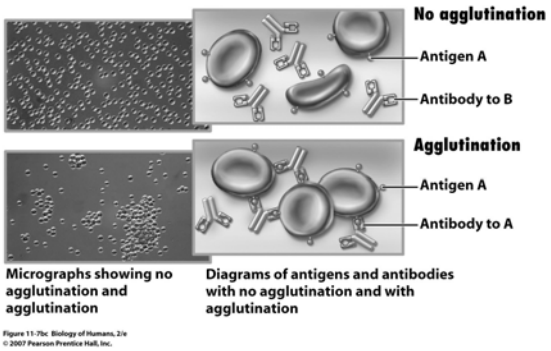
TABLE 11.2 Transfusion Relationships among Blood Types

Blood Types	Antigens on Red Blood Cells	Antibodies in Plasma	Blood Types (RBCs) That Can Be Received in Transfusions	Incidence of Blood Type in United States
A	A	Anti-B	A, O	Caucasian, 40% African American, 27% Asian, 28% Native American, 8%
B	B	Anti-A	B, O	Caucasian, 10% African American, 20% Asian, 27% Native American, 1%
AB	A and B	None	A, B, AB, O	Caucasian, 5% African American, 4% Asian, 5% Native American, 0%
O	None	Anti-A, Anti-B	O	Caucasian, 45% African American, 49% Asian, 40% Native American, 91%





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Rh Factor

- Common blood group that is also inherited
  - Name comes from the beginning letters of the Rhesus monkey where the antigen was first discovered
  - Rh-positive blood—protein antigen found on the surface of the RBC
  - Rh-negative blood—absence of this protein antigen on the surface of the RBC
- Rh-positive is most common
- Rh antibodies only develop in a person after they are exposed to the Rh factor from another's blood
  - Usually occurs between a Rh+ fetus and Rh- mother

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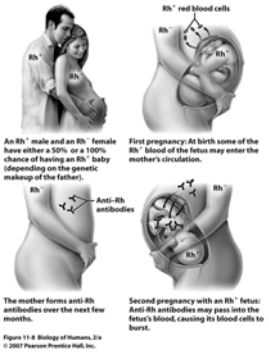
Hemolytic Disease of the Newborn



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Prevention of Hemolytic Disease of the Newborn

- Rh^- women are given an injection of anti-Rh antibodies no later than 72 hours after birth to an Rh^+ baby
- These antibodies attack the Rh antibodies formed by the mother
- Injection repeated if an Rh^- mother has another Rh^+ baby in later pregnancies

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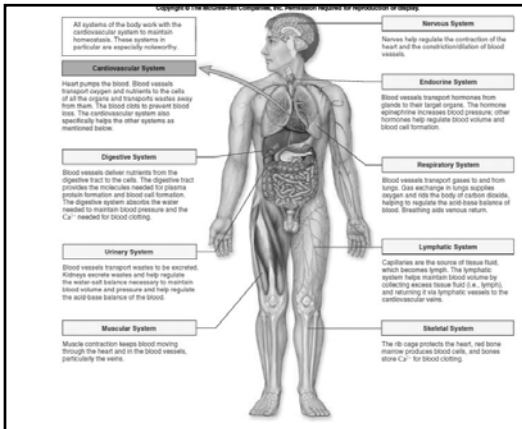

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TABLE 11.1 The Formed Elements of Blood

Type of Formed Element	Cell Function	Description	No. of Cells/mm³	Life Span
Platelets 	Play role in blood clotting	Fragments of a megakaryocyte; small, purple-stained granules in cytoplasm	250,000–500,000	5–10 days

TABLE 11.1 The Formed Elements of Blood (continued)

Type of Formed Element	Cell Function	Description	No. of Cells/mm³	Life Span
White Blood Cells (WBCs; leukocytes)				
Granulocytes				
Neutrophils 	Consume bacteria by phagocytosis	Multilobed nucleus, clear-staining cytoplasm, inconspicuous granules	3000–7000	6–72 hours
Eosinophils 	Consume antibody–antigen complex by phagocytosis; attack parasitic worms	Large, pink-staining granules in cytoplasm, bilobed nucleus	100–400	8–12 days
Basophils 	Release histamine, which attracts white blood cells to the site of inflammation and widens blood vessels	Large, purple-staining cytoplasmic granules; bilobed nucleus	20–50	3–72 hours

TABLE 11.1 The Formed Elements of Blood (continued)

Type of Formed Element	Cell Function	Description	No. of Cells/mm³	Life Span
White Blood Cells (WBCs; leukocytes)				
Agranulocytes				
Monocytes 	Give rise to macrophages, which consume bacteria, dead cells, and cell parts by phagocytosis	Gray-blue cytoplasm with no granules; U-shaped nucleus	100–700	Several months
Lymphocytes 	Attack damaged or diseased cells, or disease-causing organisms; produce antibodies	Round nucleus that almost fills the cell	1500–3000	Many years
Red Blood Cells (RBCs; erythrocytes) 	Transport oxygen and carbon dioxide	Biconcave disk, no nucleus	4–6 million	About 120 days

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