Cleveland Clinic

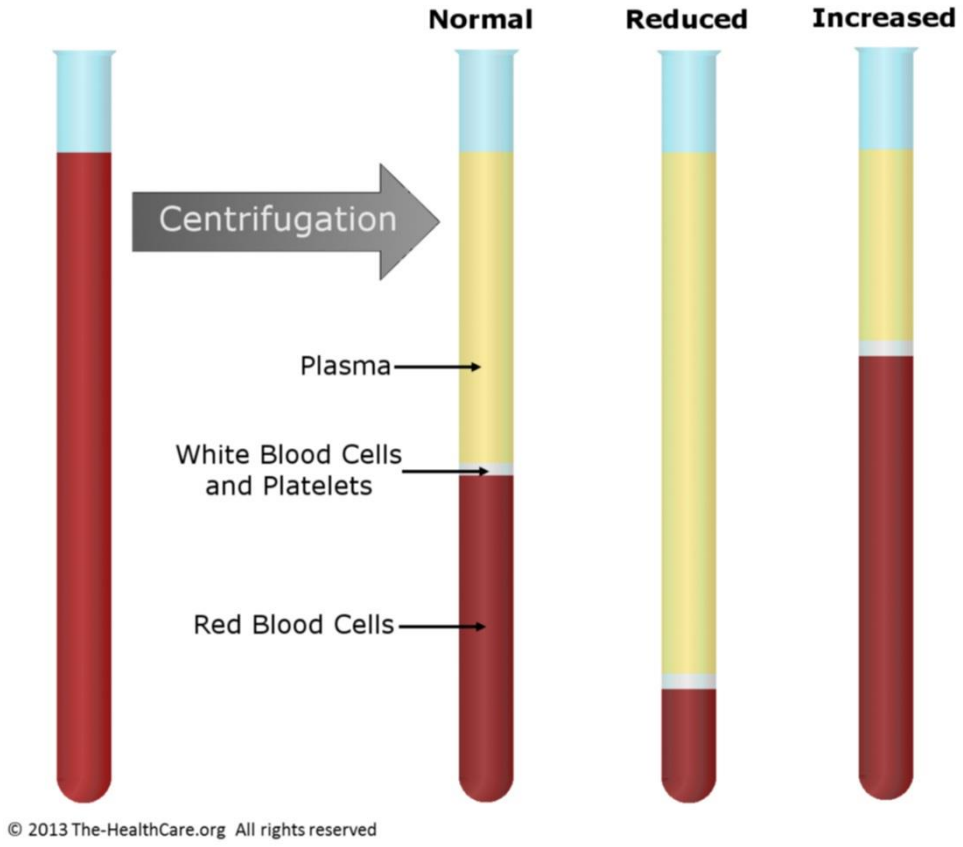
Blood Components

WHOLE BLOOD

Whole Blood

- **Storage:** 1-6°C
- **Expiration:** depends on anticoagulant
- **Dosing:** 1 unit increases Hct 3% and Hgb 1 g/dL
- Can take 48-72 hours to see results

Hemoglobin (Hgb): protein in red blood cells that carries oxygen throughout the body
Hematocrit (Hct): proportion of blood that consists of red cells

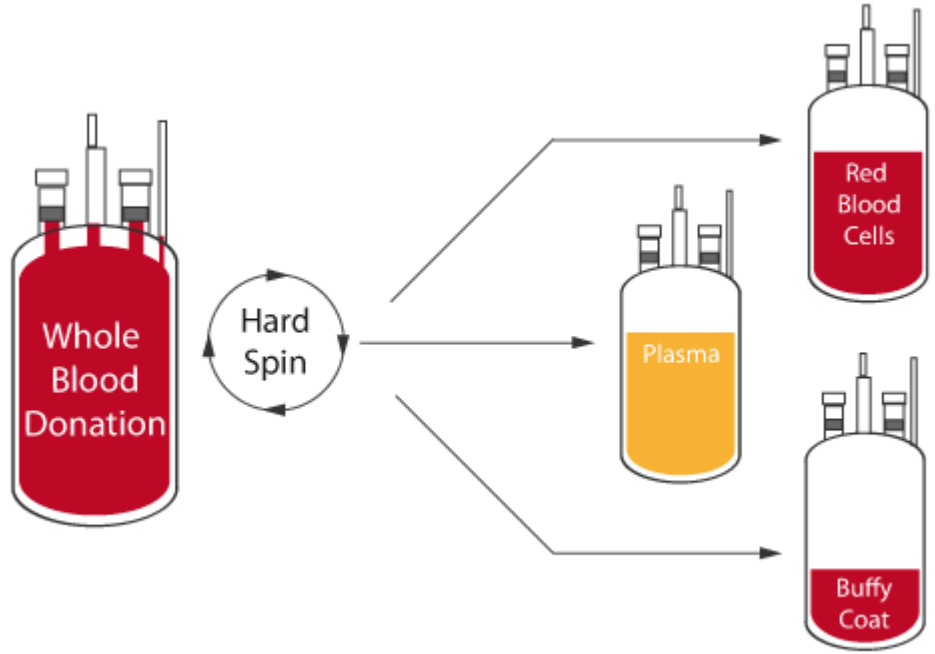


Hematocrit

RED CELL COMPONENTS

Preparation of RBCs from Whole Blood

- Use centrifuge or sedimentation
- Can prepare anytime during normal storage
- CPDA-1: remove 200-250mL plasma
- AS: remove 300 mL plasma
- Final volume: 160-275 mL of red cell
  - Anticoagulant added to total volume of about 300mL
- Also prepared by apheresis
- Whole blood used to make platelets must be cooled toward 20-24C otherwise cooled toward 1-10C
- RBCs must have a hematocrit of ≤80% without additive



Red Blood Cells

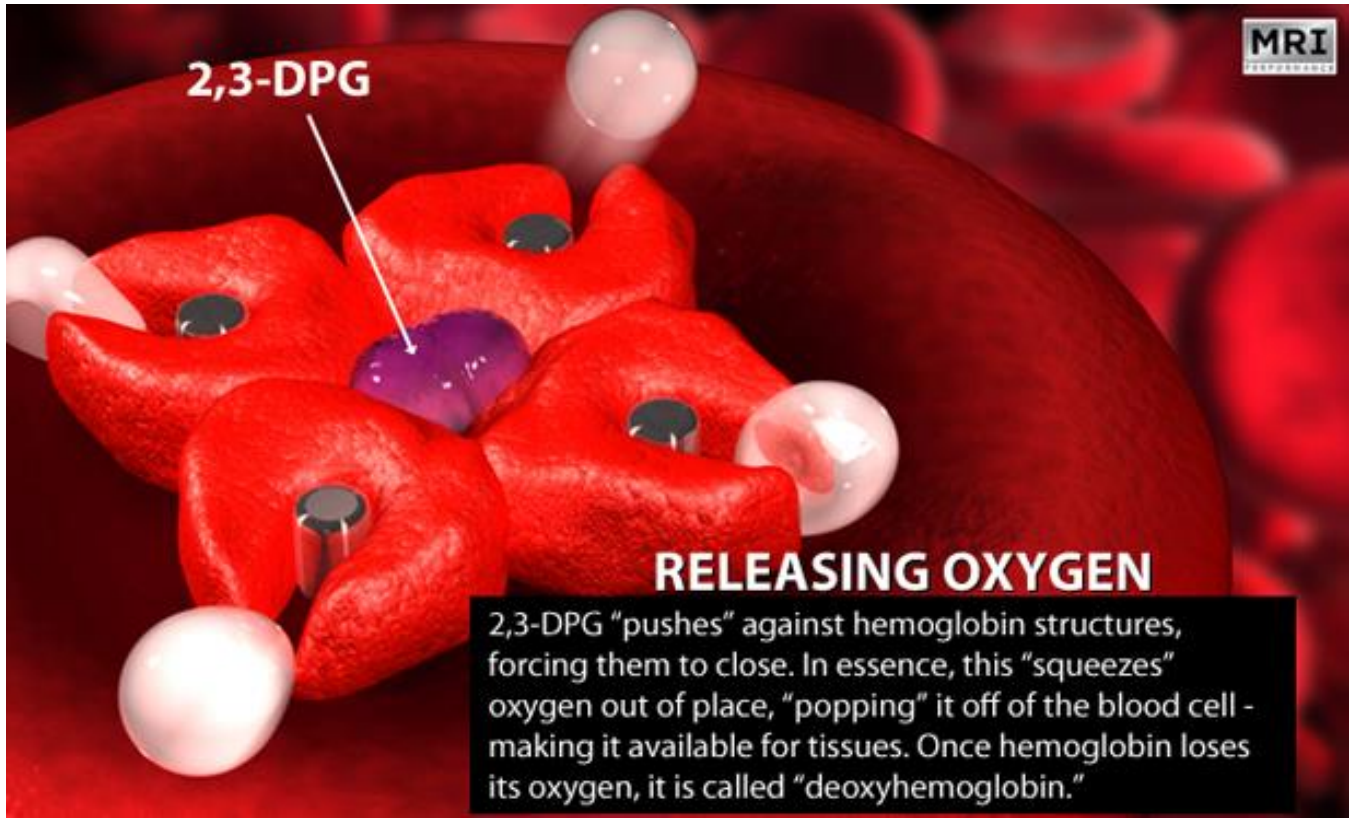
- **Storage:** 1-6°C (transport storage 1-10°C)
- **Expiration:** Depends on anticoagulant

Red Cells in Storage:

- Glucose:
  - needed for ATP production
  - decreases
- ATP:
  - keep membrane flexible, less deformable
  - decreases
- Lactic Acid:
  - end product of glycolysis/anaerobic respiration
  - Accumulates during ATP production
- pH:
  - decreases with lactic acid build-up

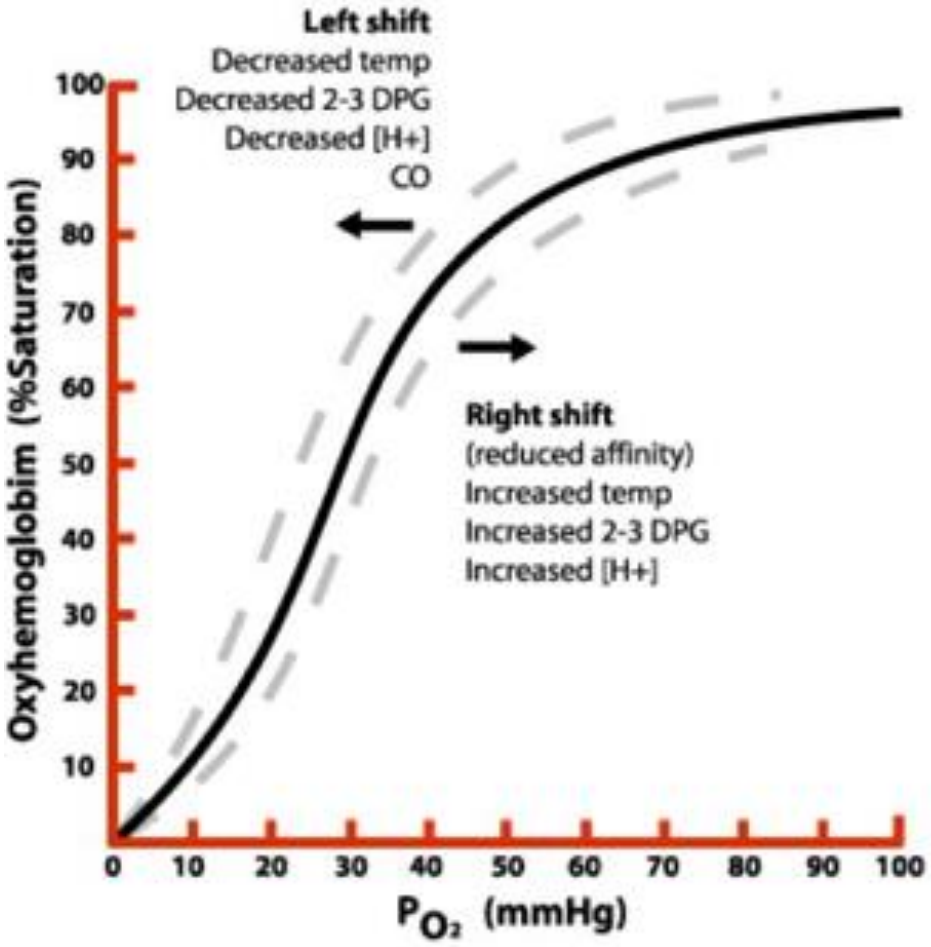
2,3-DPG

- 2,3-DPG:
  - by-product of glycolysis
  - decreases due to decreased pH activating enzyme to breakdown 2,3-DPG
  - Amount present has effect on affinity of Hgb for oxygen
  - Affects how well RBCs function post-transfusion



Red Cells in Storage

- Oxygen Dissociation curve:
  - Decreased 2,3-DPG causes increase affinity of hemoglobin to oxygen
  - This means less oxygen is delivered to the tissues
- Plasma K+:
  - Usually is actively transported into cell and transports Na+ out
  - ATP depletion causes Na+ to accumulate and K+ to be pumped out to plasma
- Plasma hemoglobin:
  - increased due to increased hemolysis of RBCs, releasing hemoglobin

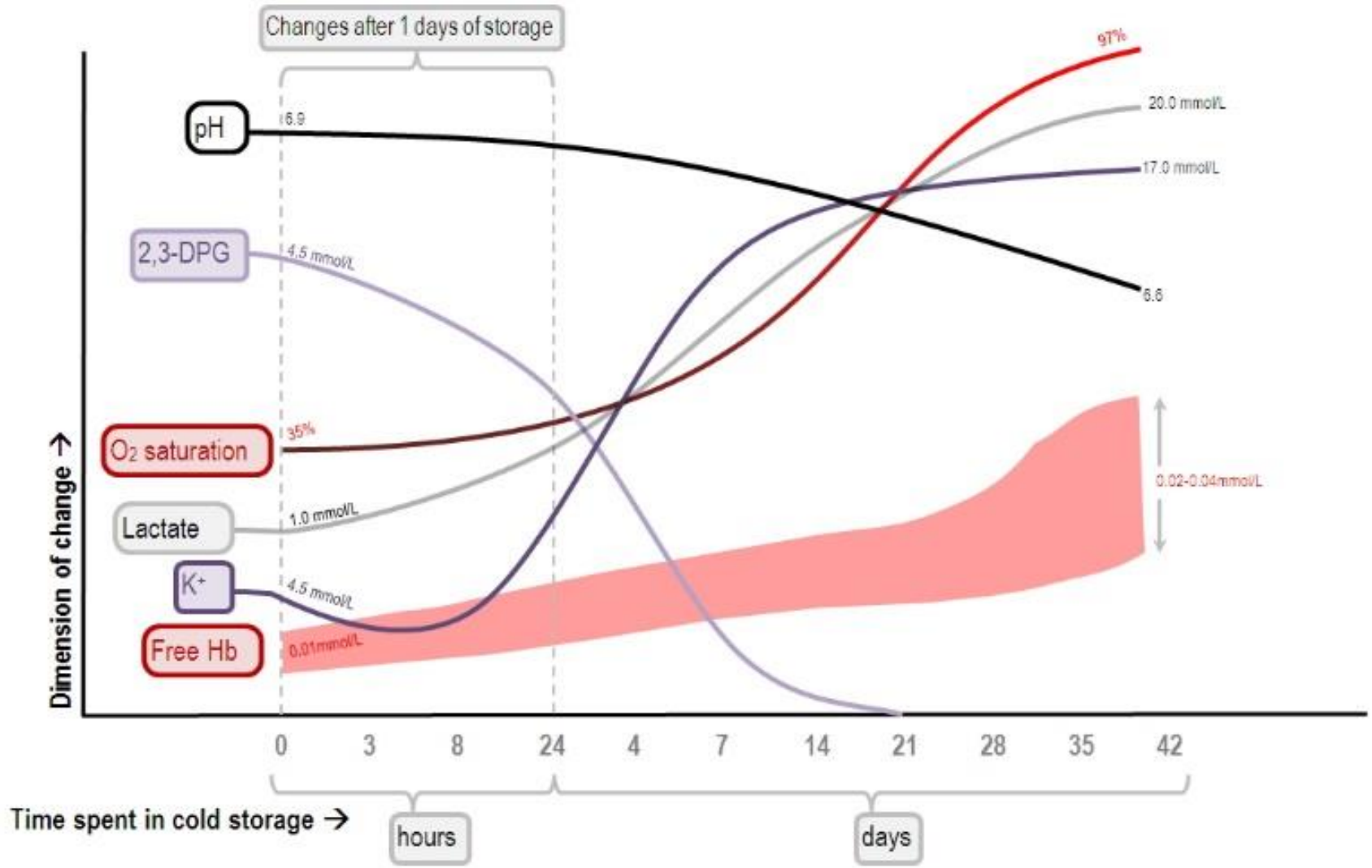


Effect of Storage on RBCs (Storage Lesion)

- **RBCs normal life span= 120 days**

Characteristic	Change Observed
% Viable Cells	Decreased
Glucose	Decreased
ATP	Decreased
Lactic Acid	Increased
pH	Decreased
2,3-DPG	Decreased
Oxygen dissociation curve	Shift to the left (increase in hemoglobin and oxygen affinity; less oxygen delivered to tissues
Plasma K+	Increased
Plasma hemoglobin	Increased

Effect of Storage on RBCs (Storage Lesion)



Chemicals in Anticoagulant Solutions

Chemical	Function
Citrate (sodium citrate/citric acid)	Chelates calcium; prevents clotting
Monobasic sodium phosphate	Maintains pH during storage; necessary for maintenance of adequate levels of 2,3-DPG
Dextrose	Substrate for ATP production (glucose)
Adenine	Production of ATP (extends shelf-life from 21-35 days)

RBC Anticoagulants

Name	Abbreviation	Chemicals	Expiration
Acid Citrate-Dextrose	ACD-A	Citrate, sodium phosphate, dextrose	21 days
Citrate-phosphate dextrose	CPD	Citrate, sodium phosphate, dextrose	21 days
Citrate-phosphate double-dextrose	CP2D	Citrate, sodium phosphate, dextrose	21 days
Citrate-phosphate-dextrose-adenine	CPDA-1	Citrate, sodium phosphate, dextrose, adenine	35 days

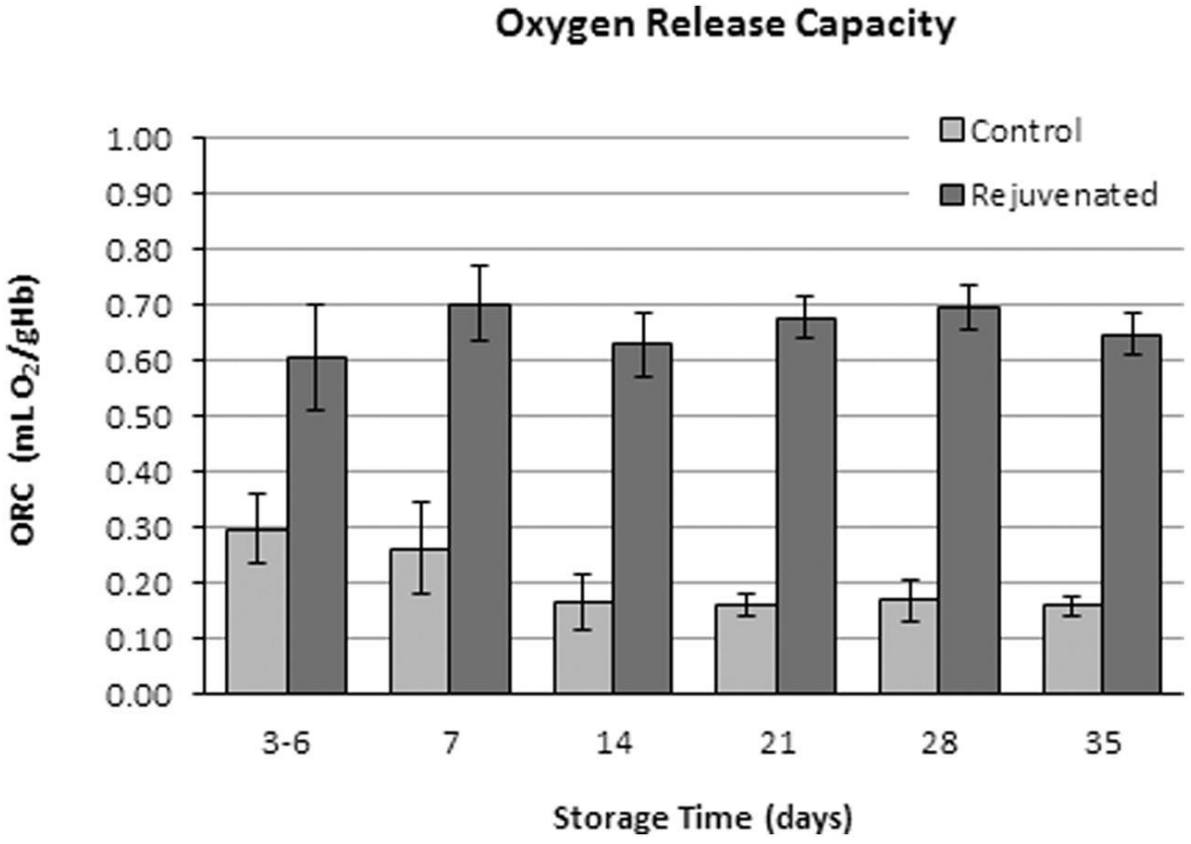
Additive Solutions (AS)

- Preserving solution added to RBC after plasma removal
- Removing plasma removes adenine and glucose
- 4 solutions:
  - Adsol (AS-1)- mannitol
  - Nutricel (AS-3)- citrate and phosphate
  - Optisol (AS-5)- mannitol
  - SOLX (AS-7)- mannitol
- All contain saline, adenine, and glucose
- **Expiration: 42 days**

RBC Rejuvenation

- Process to restore ATP and 2,3-DPG levels with metabolic alterations
- Liquid RBCs can be rejuvenated at their outdate for up to 3 days

Rejuvenation Solution contains:
- Phosphate
- Inosine
- Pyruvate
- Adenine



Frozen Deglycerolized RBCs

- RBCs frozen for long term storage
- Clinical Indications:
  - Rare blood units
  - Autologous units (many times for rare antibodies)
  - Units for special purpose (ex. Intrauterine transfusion)

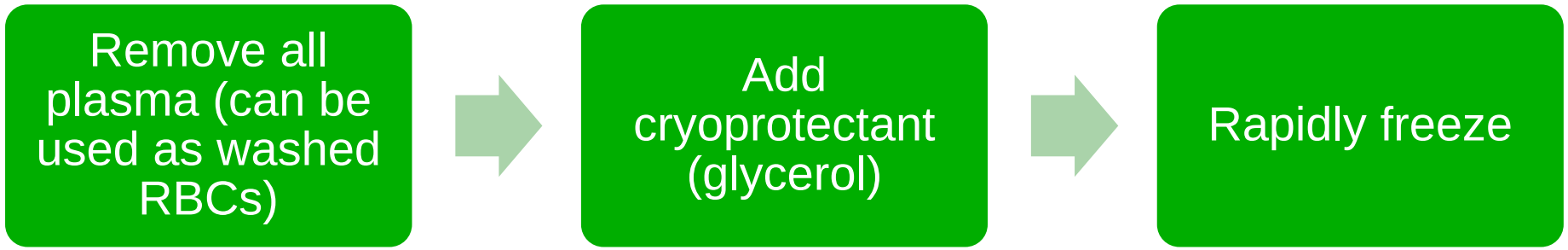
U Negative

Bombay

Rh Null

Jk(a)- Jk(b)-

Frozen Deglycerolized RBCs



- Remove cryoprotective agents to level of <1% when using (can cause RBC lysis)
- Storage: -65°C
- Expiration: 10 years frozen
  - 24 hours after thawing

PLASMA COMPONENTS

Plasma

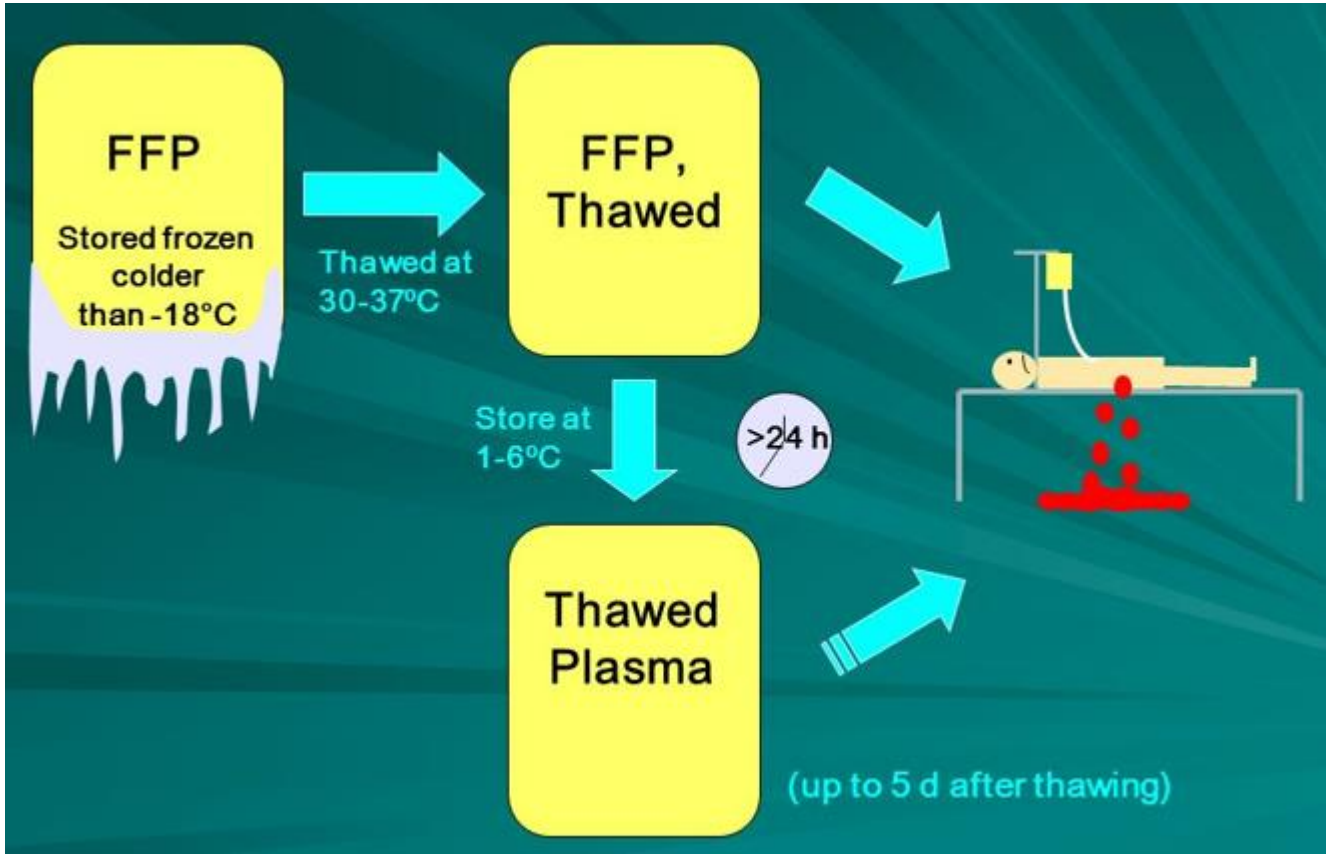
- Noncellular portion
- Primary source of coagulation factors (control blood clotting)
- **Storage:**
  - **Frozen**: -18˚C
  - **Thawed**: 1-6˚C (thawed in 30-37˚C waterbath)

CLOTTING FACTORS

Factor I	Fibrinogen
Factor II	Prothrombin
Factor III	Tissue Thromboplastin
Factor IV	Calcium Ions
Factor V	Labile Factor
Factor VII	Stable Factor
Factor VIII	Antihemophilic Factor
Factor IX	Christmas Factor, or Plasma Thromboplastin Component (PTC)
Factor X	Stuart-Prower Factor
Factor XI	Plasma Thromboplastin Antecedent (PTA)
Factor XII	Hageman Factor
Factor XIII	Fibrin Stabilizing Factor

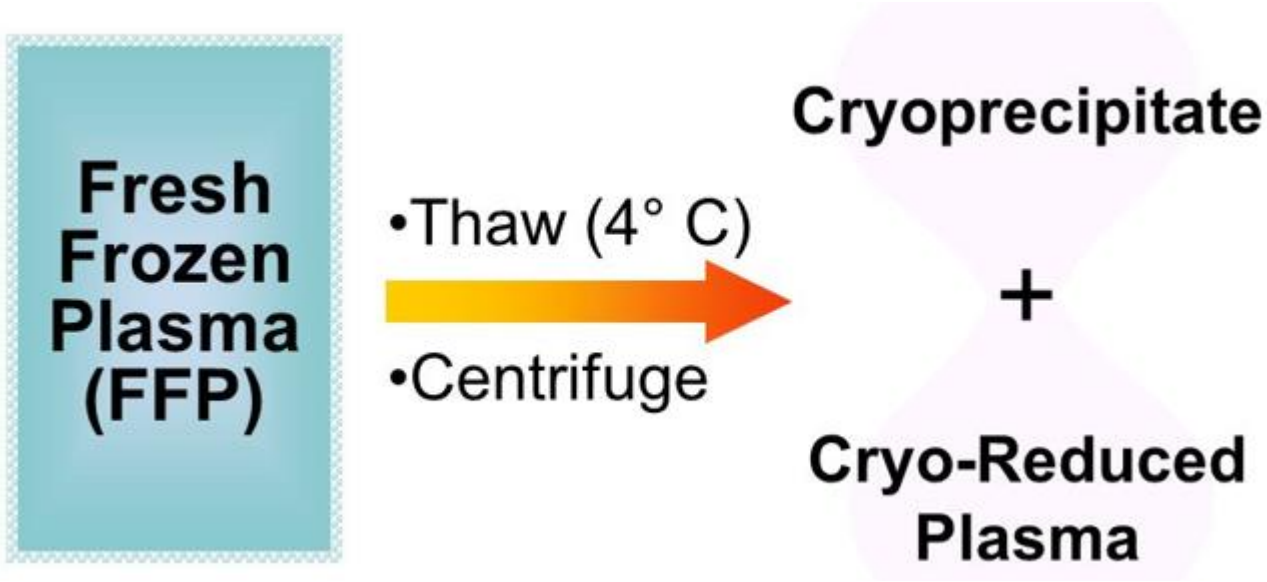
Types of Plasma

- **Fresh Frozen Plasma (FFP)**
  - Separated and frozen within 8 hours of collection
  - Thawed FFP: can be used for 24 hours
  - After 24 hours becomes Thawed Plasma: used for 4 more days (reduced Factor V and VIII)



Types of Plasma

- **Plasma Cryoprecipitate Reduced/Cryopoor plasma:**
  - Thaw frozen plasma at 1-6° C, precipitate (cryo) is removed, remainder of plasma refrozen
  - Removes Factors VIII, XIII fibrinogen, vWF, cryoglobulin, fibronectin
  - Frozen within 24 hours
  - Rarely used



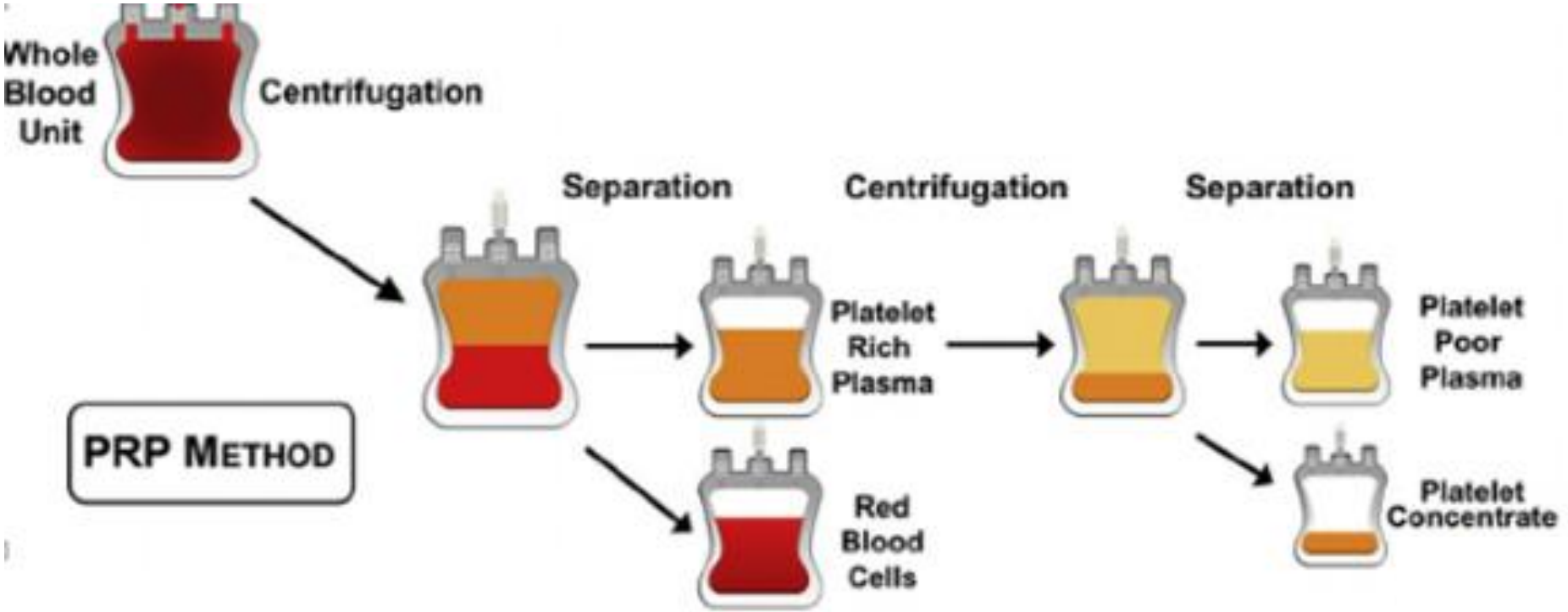
Types of Plasma

- **Plasma Frozen within 24 hours of collection (FP24)**
  - Slightly reduced levels of Factor VIII
  - Stored, thawed, transfused same as FFP
- **Liquid Plasma:**
  - Rarely used
  - Never frozen, kept at 1-6° C
  - Transfused up to 5 days after whole blood expiration

Preparation of Plasma

- **From whole blood:**
  - Centrifuge for a short light spin (2-3 min, 3,200 rpm)
  - Separate plasma from RBCs- must leave some plasma on RBCs to maintain Hct of 70-80% in RBC
  - Centrifuge plasma with heavy spin (5 min, 3,600 rpm)
    - Separates plasma from platelets
  - Take off plasma and freeze
    - 50-70 mL of platelets are left at the bottom and collected
- **Can also be apheresis**

Plasma Preparation



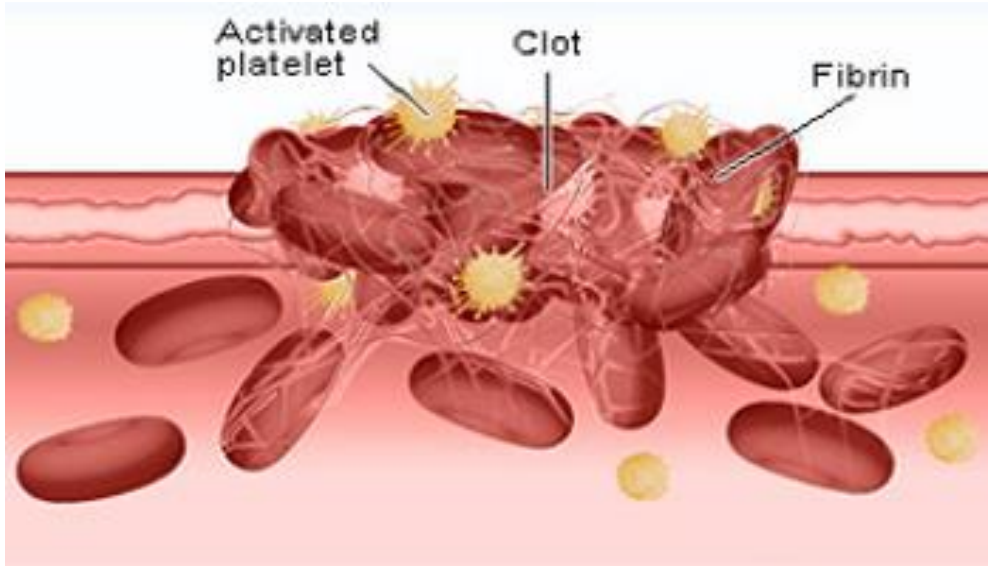
Expiration of Plasma

- **Frozen:** 1 year
- **Thawed:**
  - 24 hours for labile clotting factors
  - 5 days (for stable clotting factors)

PLATELET COMPONENTS

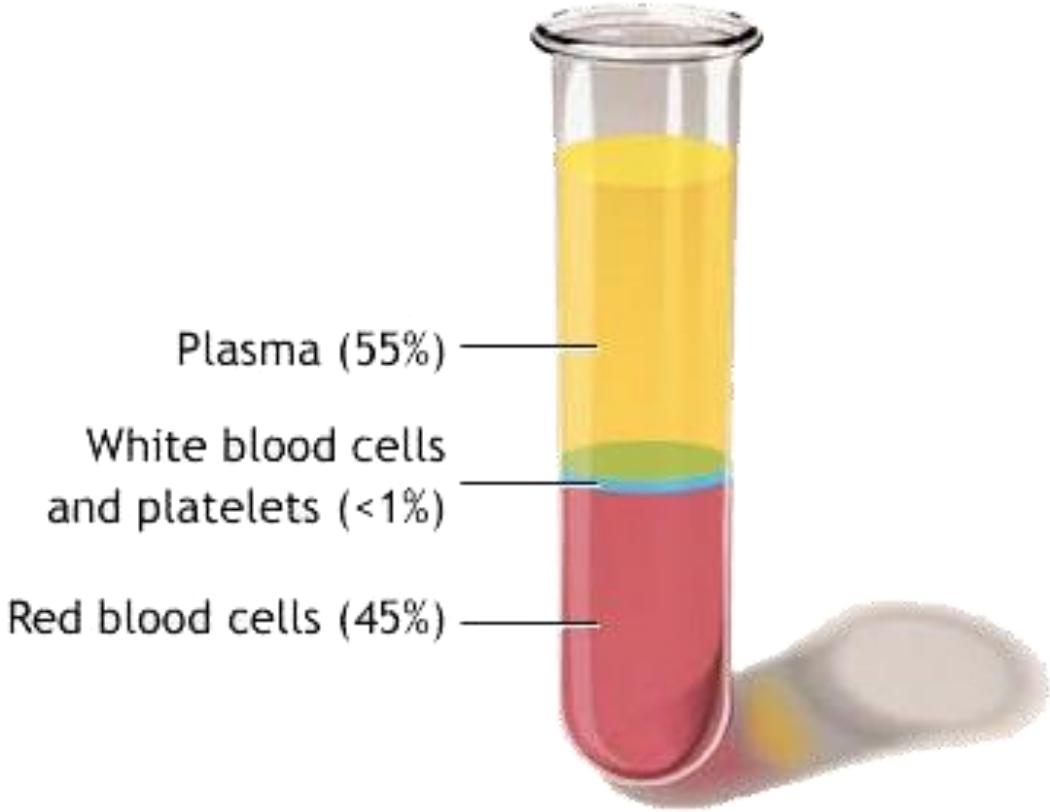
Platelets

- Forms hemostatic plug- aids in clotting to stop bleeding
- **Storage:** 20-24°C
  - Constant agitation- facilitates oxygen transfer/consumption
  - Max. time without agitation during transport is 30 hours
- **Expiration**: 5 days (some cases 7 days)

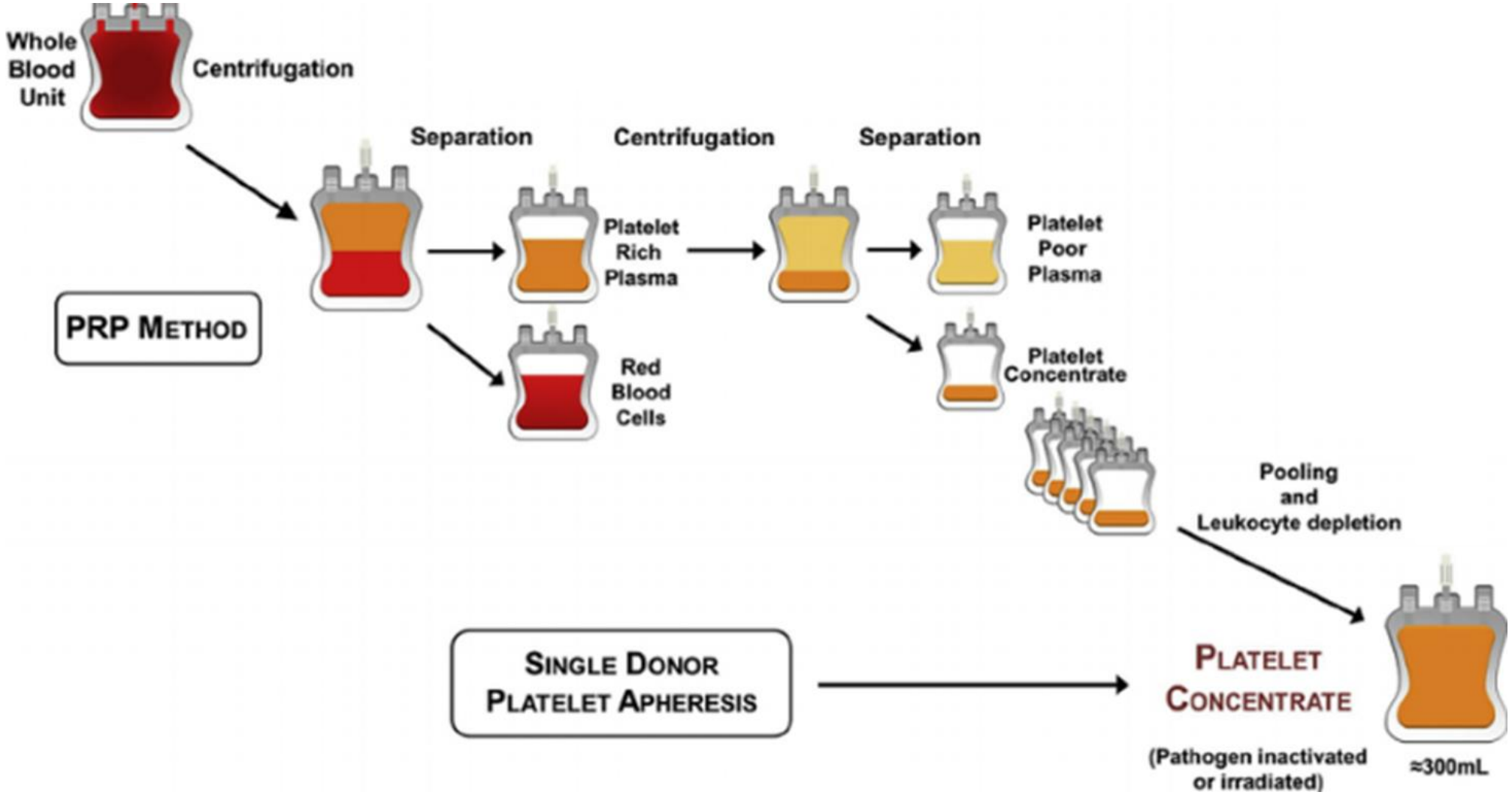


Preparation of Platelets

- Same as plasma
- The platelet pellet left at the bottom is resuspended in a small amount of plasma
- Pool 4-5 platelet concentrates to make one pooled platelet
- Must be separated from whole blood within 8 hours of collection

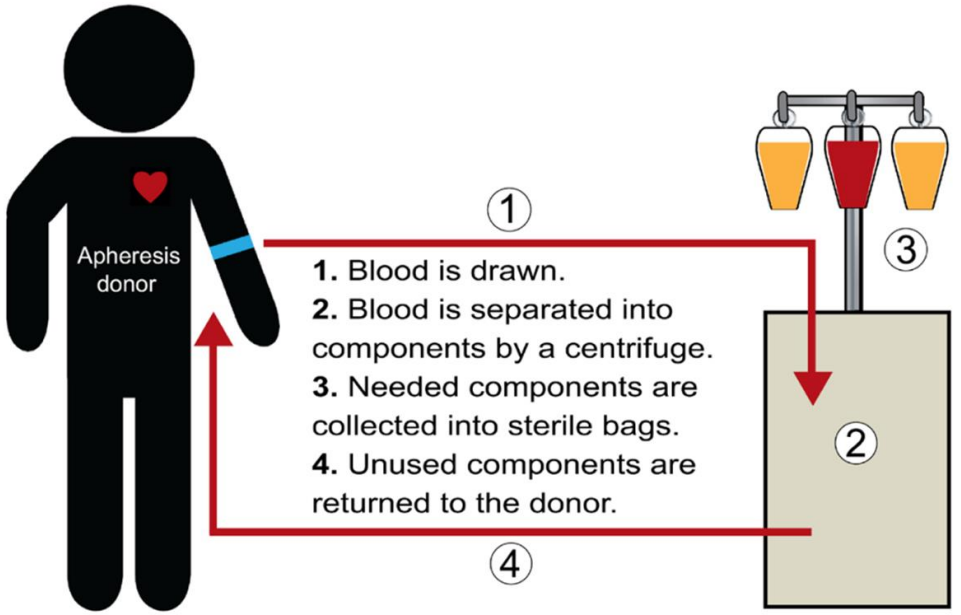


Preparation of Platelets



Types of Platelets

- **Apheresis Platelets**
  - From a single donor
  - Filter platelets from blood while collecting
  - Each platelet must contain **$3x10^{11}$** platelets
  - Increase platelet count by **20,000-60,000 per µL**



Types of Platelets

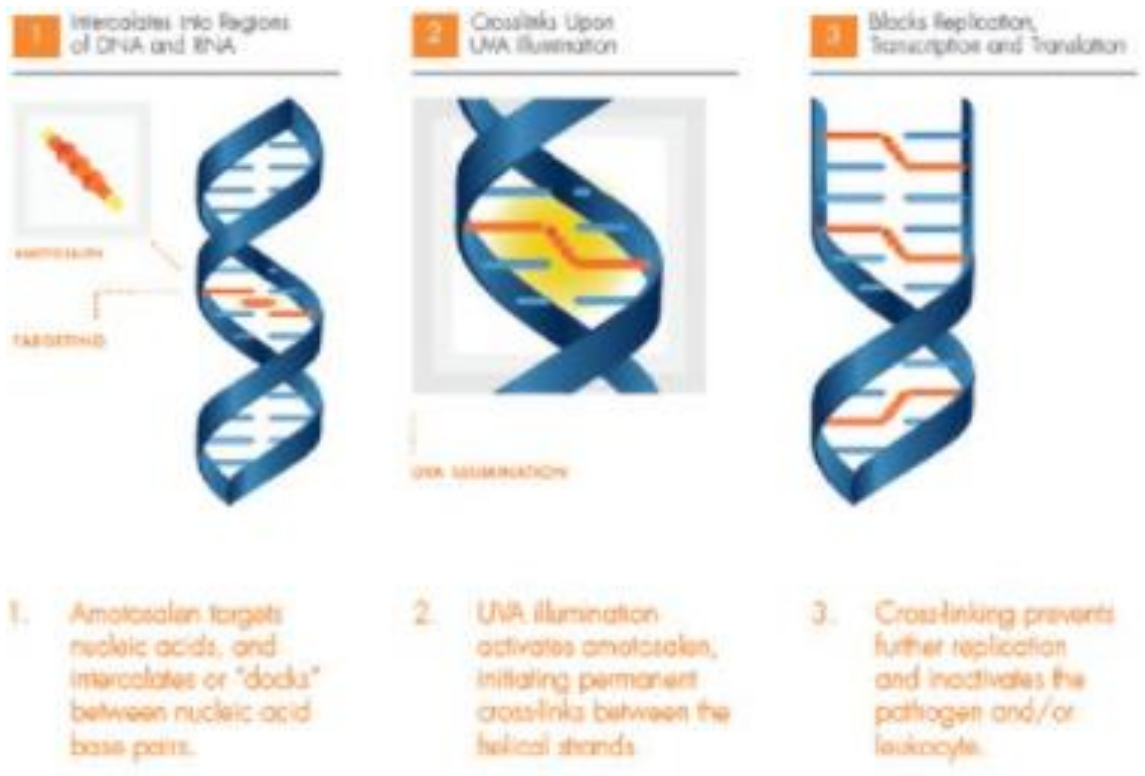
- **Platelet Pool or Random Platelet:**
  - 4-6 platelet concentrates pooled together
  - Must have **$5.5x10^{10}$** platelets from one whole blood unit
  - Should have total of $3x10^{11}$ once pooled
  - One platelet concentrate increases platelet count 5,000-10,000 platelets/µL
  - One platelet pool increases platelet count 20,000-60,000 platelets/µL
  - Suspended in 40-70 mL of plasma

Platelet Testing

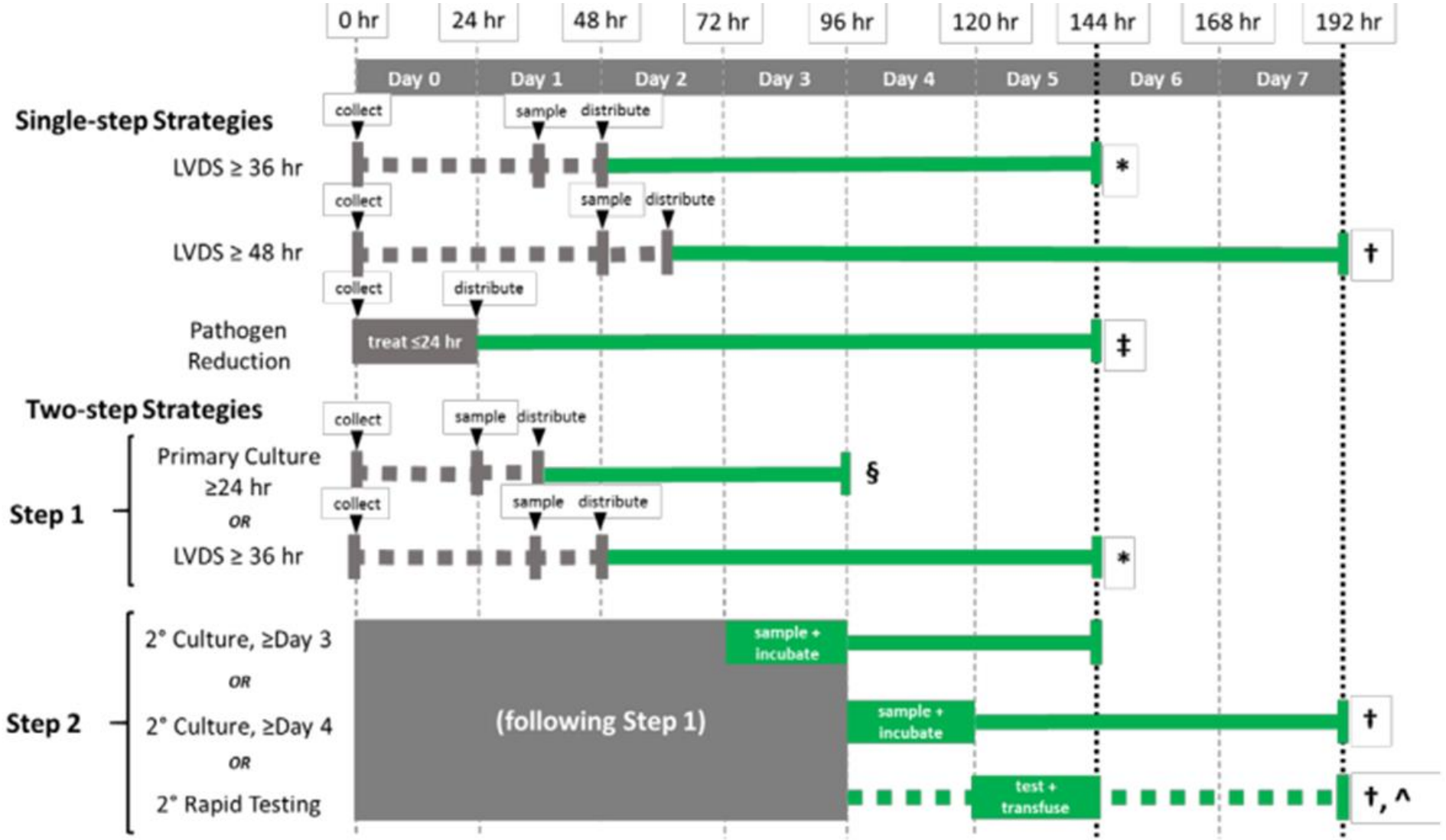
- **Platelet count – ensure >** $3x10^{11}$
- WBC count – leukoreduced $<5x10^{6}$
- pH ≥6.2
- Bacterial testing – ensure no bacterial contamination (LVDS platelets and PR platelets being used to reduce bacterial contamination)

Pathogen Reduced (PR) Platelets

- Treat platelet components to reduce or inactivate any residual pathogens
- Adds an additional level of safety
- Uses amotosalen (psoralen)- a molecule that is activated by ultraviolet A light and binds to nucleic acid base pairs of pathogens preventing replication
- Don’t need to be cultured for bacterial testing
- Also removes the need for irradiation since it inactivates WBC replication



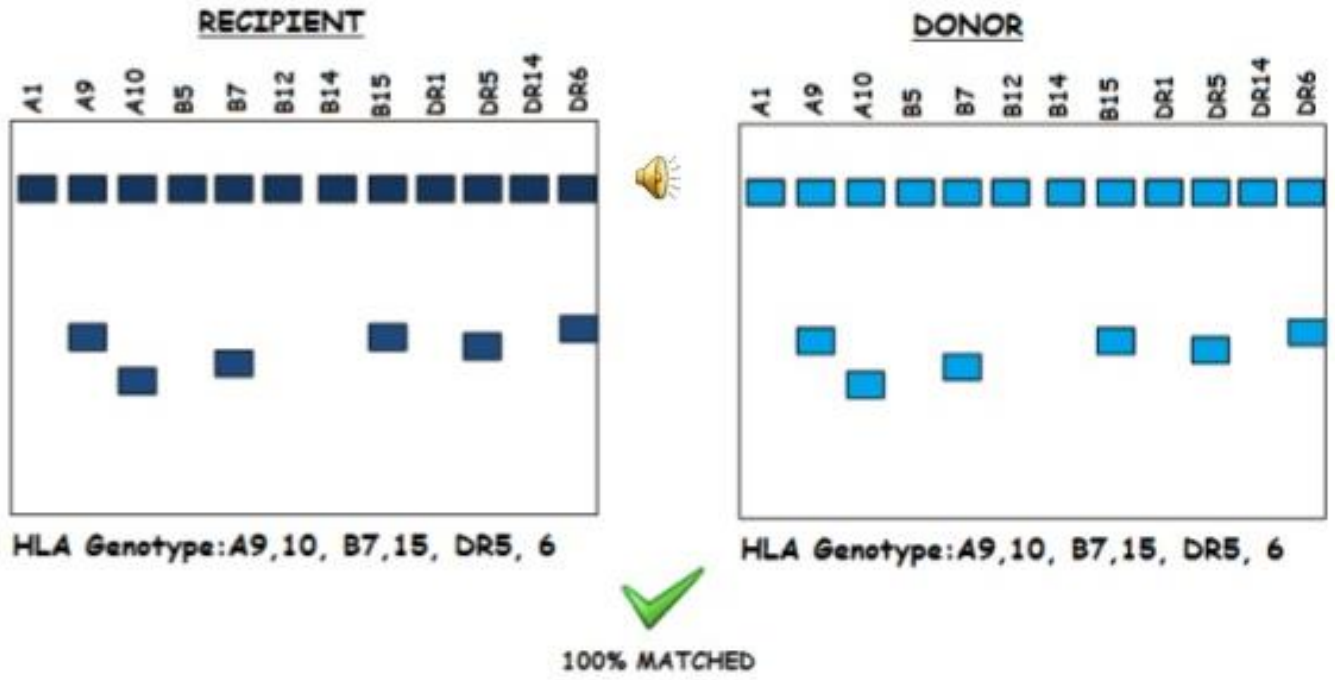
Reducing Bacterial Contamination Risk



HLA Platelet

- Patient who has made HLA antibodies can destroy donor platelets
- Cause platelet refractoriness- failure to achieve desired platelet count after platelet transfusion

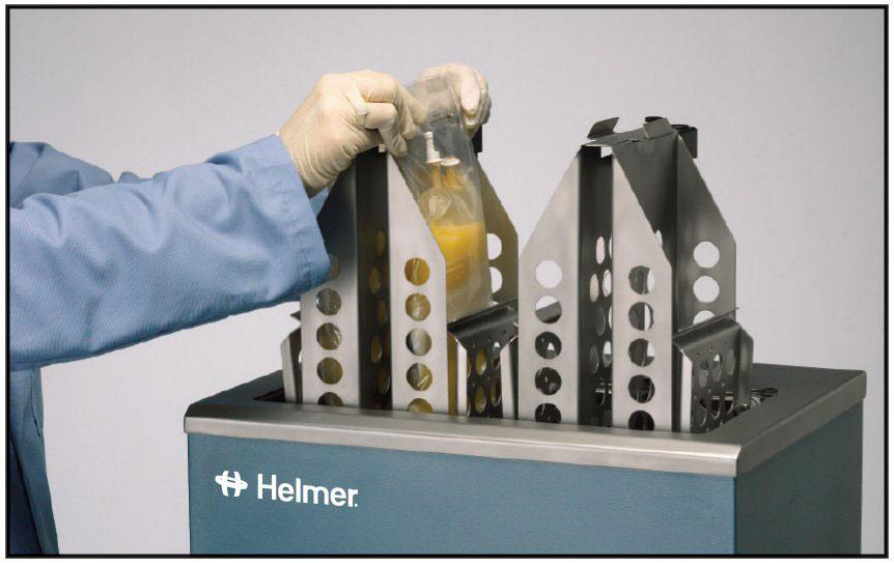
- Receive HLA matched platelets with the same haplotype
- If none available give pooled platelets
  - 5 different donors
  - 5 chances of having matched platelets



CRYOPRECIPITATE

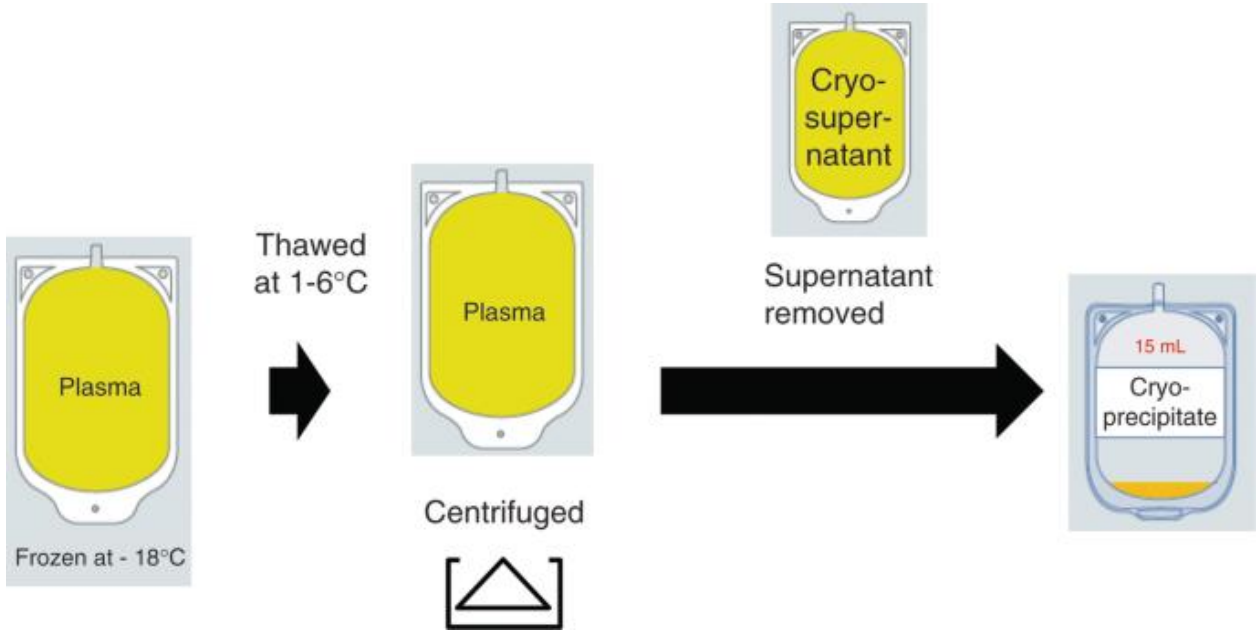
Cryoprecipitate

- Part of whole blood containing concentrate of fibrinogen, factor VIII, vWF, Factor XIII, and fibronectin
- **Storage:**
  - Frozen: -18˚ C
  - Thawed: 20-24˚ C (in 30-37˚ C water bath)
- **Expiration**: 1 year frozen



Preparation of Cryoprecipitate

- Only prepared from whole blood
- FFP is frozen and then thawed at 1-6°C
- Separate insoluble precipitate from plasma
- Centrifuge plasma at 4°C for hard spin
- Take plasma off- cryo is left at the bottom
- Resuspend cryo in 10-15mL of plasma
- Refreeze cryo within an hour



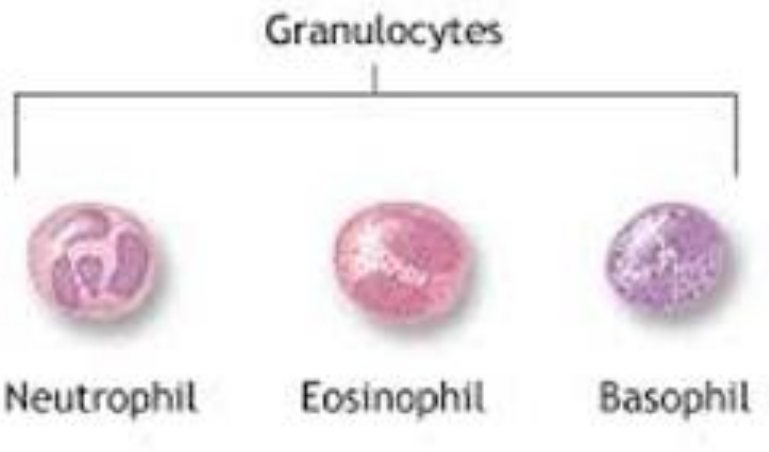
Types of Cryoprecipitate

- Cryoprecipitate Concentrate- Cryo removed from one plasma unit
  - Expiration after thawing: 6 hours
- Pooled Cryoprecipitate- pool cryo from 5 plasma units
  - Expiration after thawing: 6 hours for closed system, 4 hours for open system

GRANULOCYTES

Granulocytes

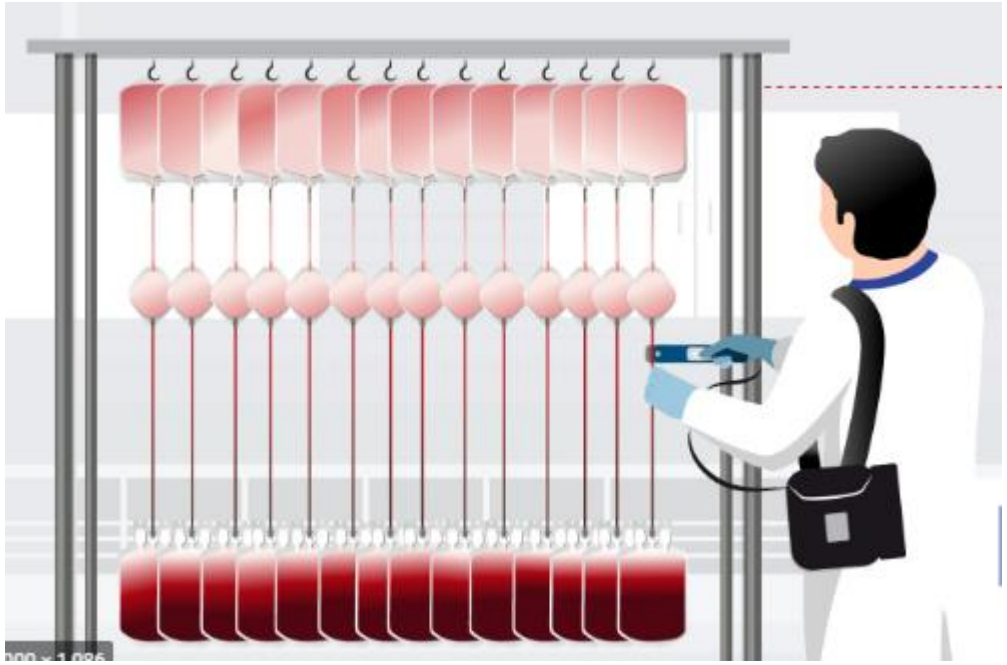
- White blood cells characterized by presence of granules in cytoplasm (neutrophils, eosinophils, basophils)
- Usually contains large number of RBCs (>2 mL)
- **Storage:** 20-24°C No agitation
- **Expiration:** 24 hours from collection
  - Granulocyte function decreases very rapidly
- **Collection:** Apheresis
- **Testing**: contain at least 1 x 10^{10} granulocytes

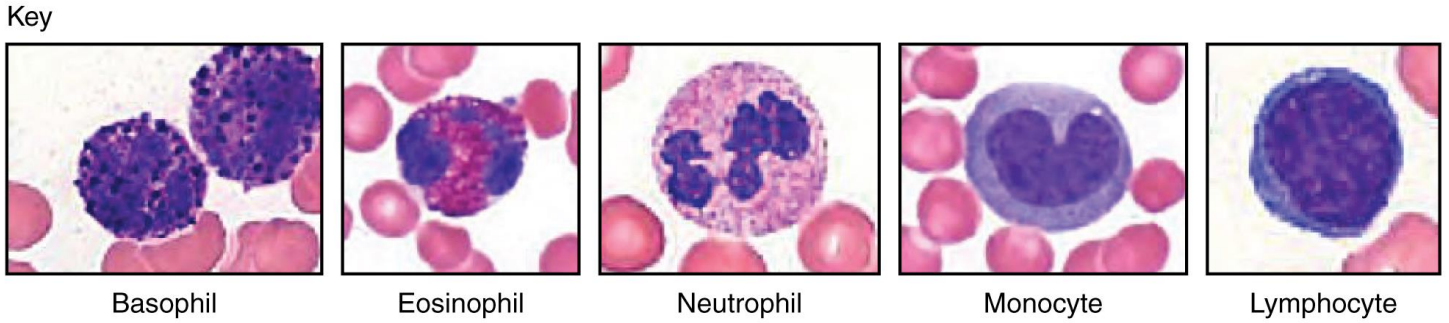


BLOOD PRODUCT MODIFICATIONS

Leukocyte-Reduced RBCs

- Remove leukocytes from RBCs
- Average unit of RBCs: $2x10^9$ leukocytes
- Leukocytes can cause:
  - Febrile non-hemolytic transfusion reactions
  - Transfusion associated Grafts-vs.-Host Disease (TA-GVHD)
  - Transfusion related immune suppression
  - May harbor cytomegalovirus (CMV)



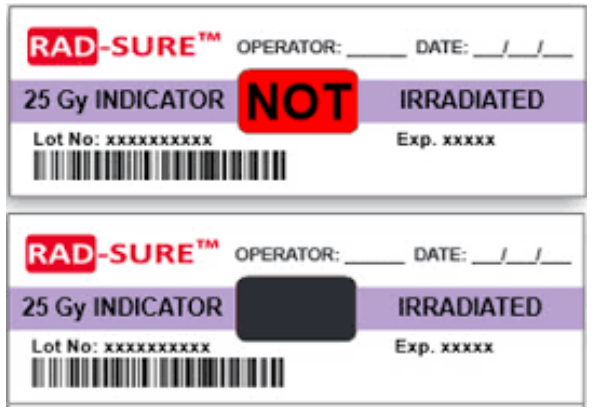


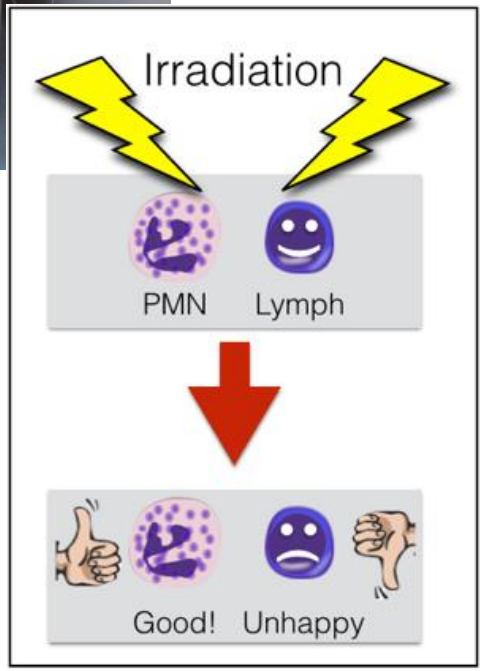
Leukocyte-Reduced RBCs

- Must reduce leukocytes to $5x10^6$
- Filters used to leuko-reduce
- Usually end with $<1x10^6$ leukocytes
- Almost all RBCs are now leuko-reduced

Irradiation

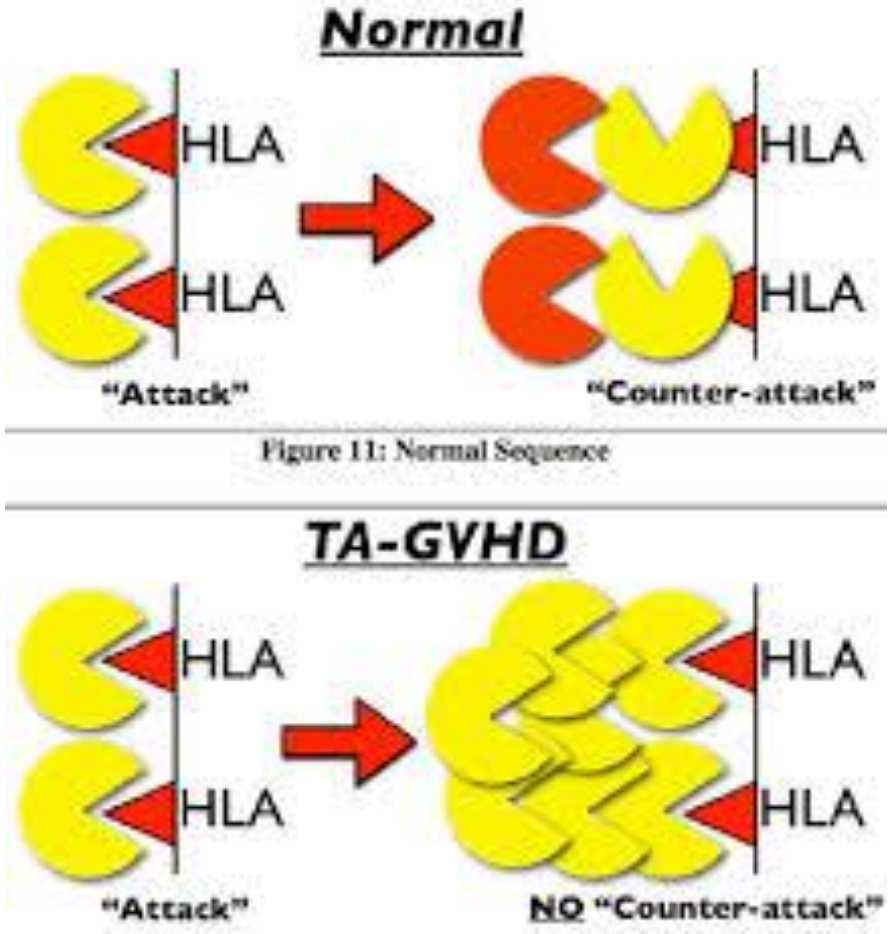
- Decreases mitogenic capacity of transfused T-cells making them immunoincompetent
- **Use:** prevent Transfusion Associated Graft-vs-Host Disease
- Three conditions necessary for TA-GVHD:
  - Transfuse immunocompetent T-lymphocytes
  - Histocompatibility differences between donor and recipient
  - Immunocompromised patient





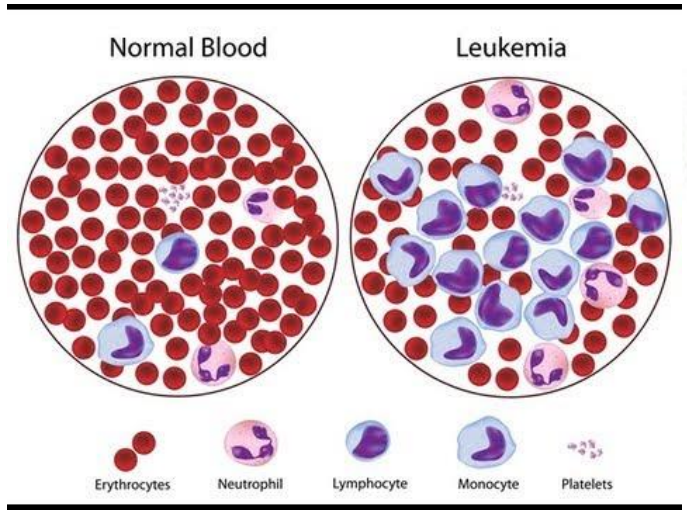
TA-GVHD Disease Cause

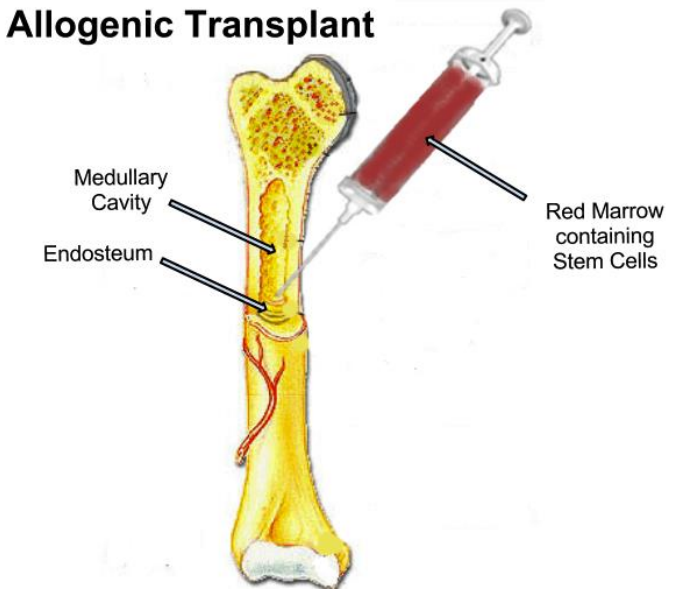
- Transfused T-lymphocytes mount immune response against foreign (recipient) HLA host tissues
- Normally: host lymphocytes counterattack, neutralizing
- Immunocompromised patients: no counterattack, continued T-lymphocyte attack on host causing TA-GVHD



Clinical Indications for Irradiation

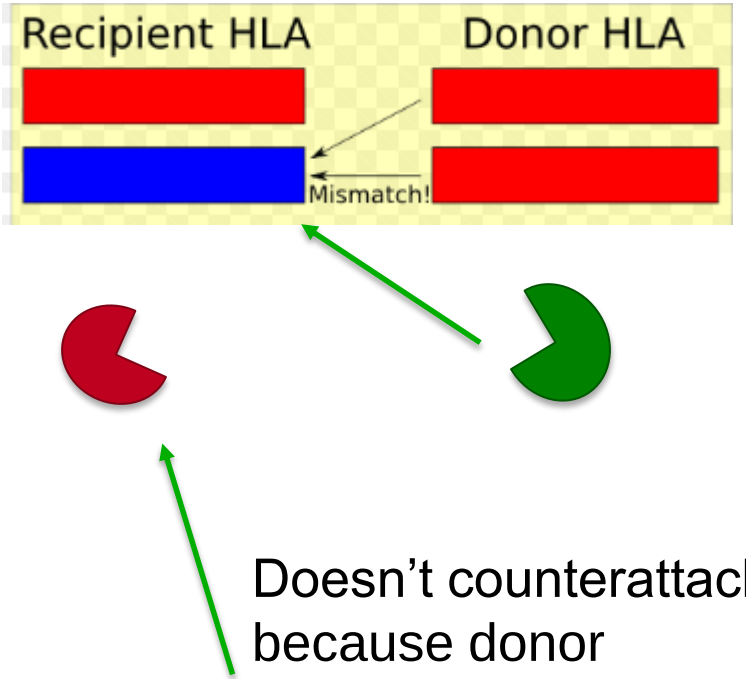
- Congenital immunodeficiencies
- Hodgkin's Lymphoma, leukemia
- Bone Marrow Transplant
- Intrauterine/Neonatal Transfusion
- HLA matched platelets
- Donation from blood relatives
- Oncology patients/chemotherapy





Donation from Blood Relatives

- Donor:
  - homozygous for HLA haplotype shared with heterozygous recipient
- Recipient
  - doesn't recognize homozygous HLA haplotype as foreign
  - doesn't eliminate donor T-lymphocytes
- Donor T-lymphoctyes:
  - recognize recipient non-shared haplotype as foreign
  - Mount immune attack

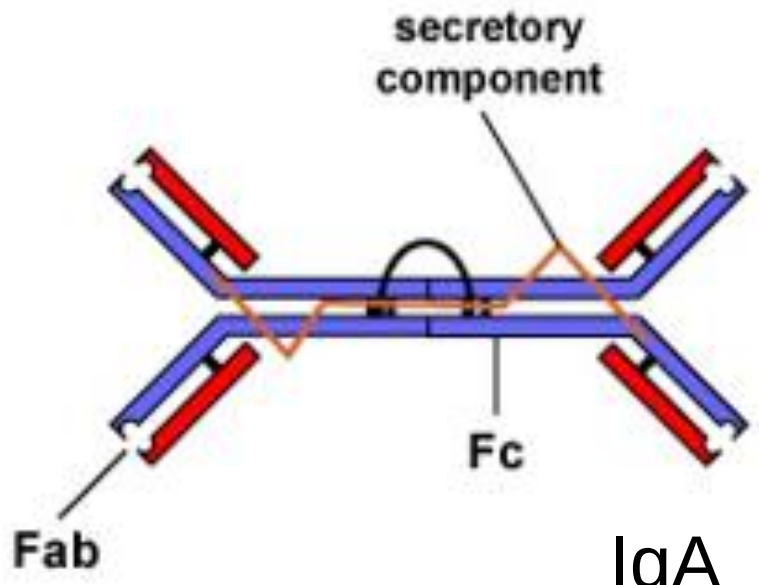


Irradiated Blood Products

- Only red cells, platelets, and granulocytes need to be irradiated
- Plasma and cryoprecipitate do not contain white blood cells
- Irradiation decreases RBC expiration date to 28 days from collection
- Platelet and granulocyte expiration remain the same due to their short expiration periods

Washed RBCs

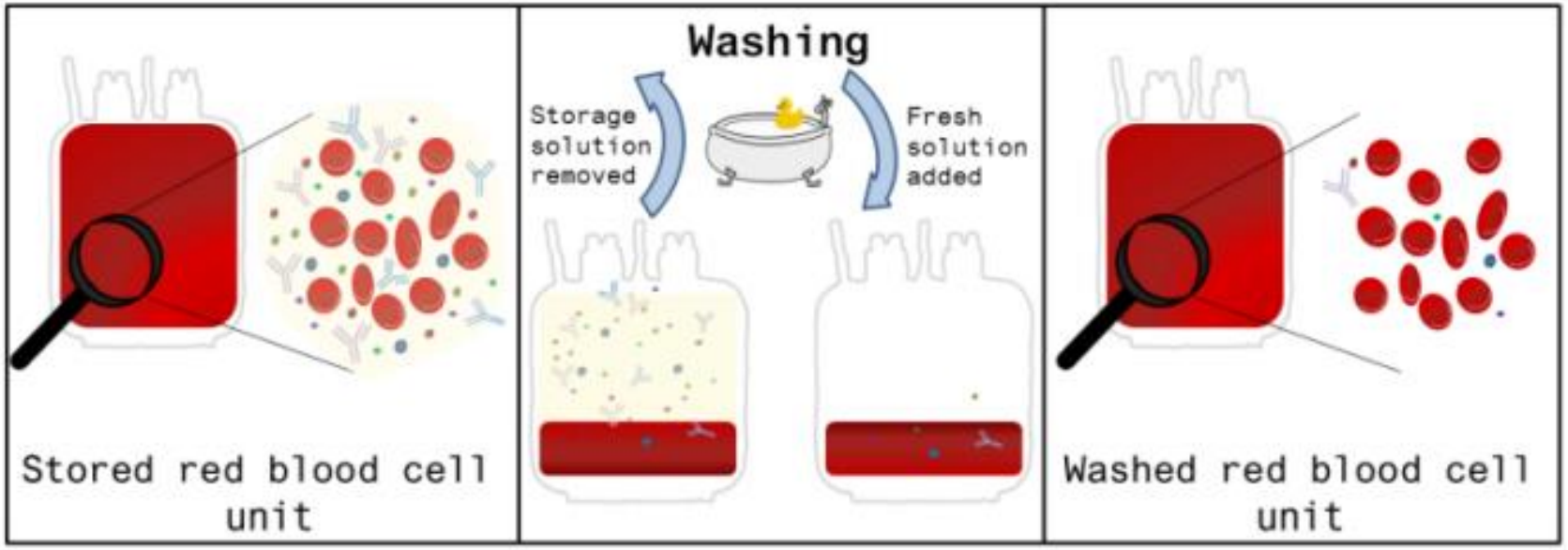
- Removes plasma and proteins
- Clinical Indications
  - Patients with severe allergic reactions (usually to proteins)
  - IgA deficient patients- make anti-IgA which attaches to IgA in donor plasma



IgA

Washed RBCs

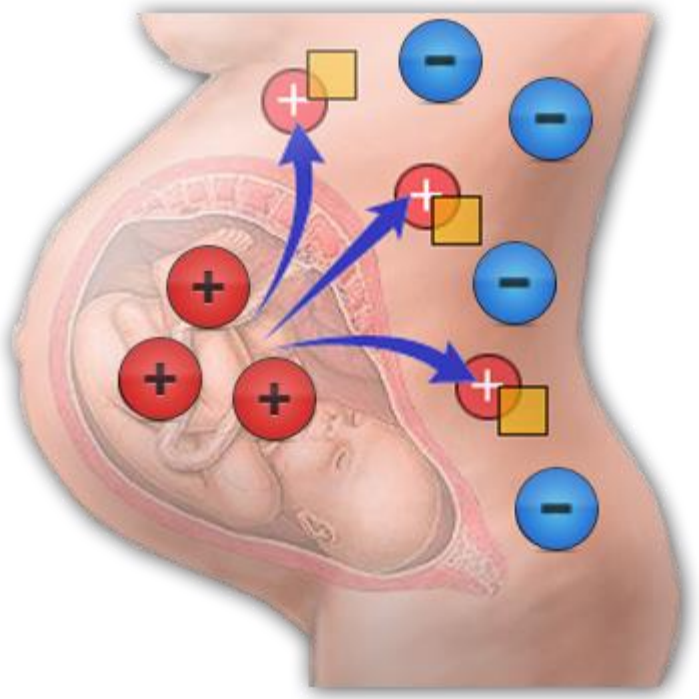
- RBCs are centrifuged, storage solution removed, saline added, and supernatant purged repeatedly until only RBCs left
- **Expiration:** changes to 24 hours



PLASMA DERIVATIVES

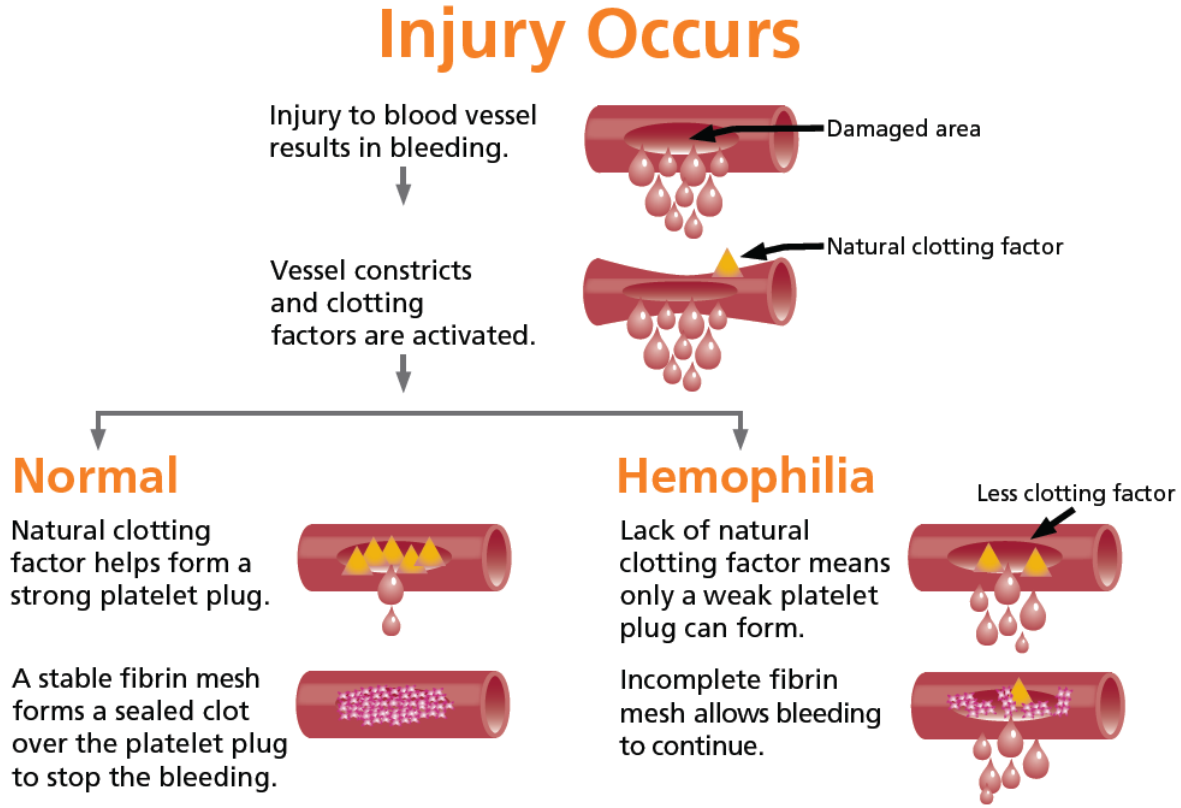
Plasma Derivatives

- Concentrates of specific plasma proteins prepared from pools of plasma
- **Rh Immune Globulin (RhIG or Rhogam):**
  - Concentrated IgG anti-D
  - Protect Rh negative female from Rh pos infant
  - Attaches to D+ RBCs making it into mother's system
  - Prevents sensitization to D antigen



Plasma Derivatives

- **Activated Factor VII-** Hemophilia A and congenital factor VII deficiency
- **Factor VIII Concentrate-** Hemophilia A, classical hemophilia
- **Factor IX Concentrate-** Hemophilia B
  - Significant levels of vitamin K-dependent factors



Adapted from: Human Disease: Blood Clot Disease (Hemophilia). Jan 26, 2015. Accessed at: http://humansanatomy.org/2015/01/26/blood-clot-disease-hemophilia/ on 02.26.2015.

Plasma Derivatives

- **Albumin-** hypovolemia, hypoproteinemia, shock and burn patients
  - 96% albumin, 4% globulins
- **Immune Globulins-** immunodeficiency disease, ITP, post-transfusion purupura, HIV-related thrombocytopenia, passive antibody prophylaxis against hepatitis and herpes
  - Concentrate of plasma gamma globulins

Blood Component Labeling Requirements

- Name of blood component
- Collection facility
- Unique facility identifier (FDA registration number)
- Donation identification number
- Anticoagulant or preservative
- Approximate volume
- Storage temperature
- Expiration date, and if needed, expiration time
- ABO and Rh
- Volunteer or Paid donor
- Number of units in pool if needed
- Instructions to the transfusionist:
  - Rx only
  - May transmit infectious agents
  - Identify intended recipient
  - See Circular of Information

Cleveland Clinic

Every life deserves world class care.