Section 3
Basic Blood Facts

Aim

- To introduce the basic concepts of haematology, blood components and blood products and how they interlink with Intraoperative Cell Salvage (ICS) and blood conservation

Learning Outcomes

- Describe the main functions of blood
- Identify the main components of blood and describe their individual functions
- Describe basic coagulation
- List the allogeneic (donor) blood components available for clinical use
- Identify the allogeneic (donor) blood products available for clinical use
- Identify the recombinant therapies available for clinical use

Introduction

Before considering ICS it is important to understand the composition and function of whole blood as well as the functions of the main components of blood and how these components can be separated.

3.1 Functions of Blood

Human blood is a collection of cells suspended in liquid and has the following definable functions:

- Transport:
  - Dissolved gases (e.g. oxygen, carbon dioxide)
  - Waste products of metabolism (e.g. water, urea)
  - Hormones, enzymes and nutrients
  - Plasma proteins (associated with defence, such as blood clotting and antibodies)
  - Blood cells (including white blood cells and red blood cells)
- Maintenance of body temperature
- Control of pH:
  - The pH of blood must remain in the range 6.8 to 7.4 otherwise cells become damaged
- Removal of toxins from the body:
  - The kidneys filter all of the blood in the body (approximately 8 pints), 36 times every 24 hours. Toxins removed from the blood by the kidneys leave the body in the urine. Toxins also leave the body in the form of sweat.
- Regulation of body fluid electrolytes:
  - Excess salt is removed from the body

3.2 Composition of Blood

Blood has both cellular and non-cellular components, each accounting for approximately half of the total volume. The cellular components, which are produced in the bone marrow, include red blood cells (RBCs), white blood cells (WBCs) and platelets. The non-cellular component of blood is plasma which is primarily water. Plasma contains proteins such as albumin, clotting factors, immunoglobulin and electrolytes. Blood constitutes about 7% of body weight, which is 70ml/kg.

Haemoglobin (Hb) is a complex protein-iron compound in the blood that carries oxygen to the cells from the lungs and carbon dioxide away from the cells to the lungs. Each red blood cell contains 200 to 300 million molecules of haemoglobin. Each molecule of haemoglobin contains several molecules of haem, each of which can carry one molecule of oxygen. The normal concentration of haemoglobin is between 125 and 160g/l.

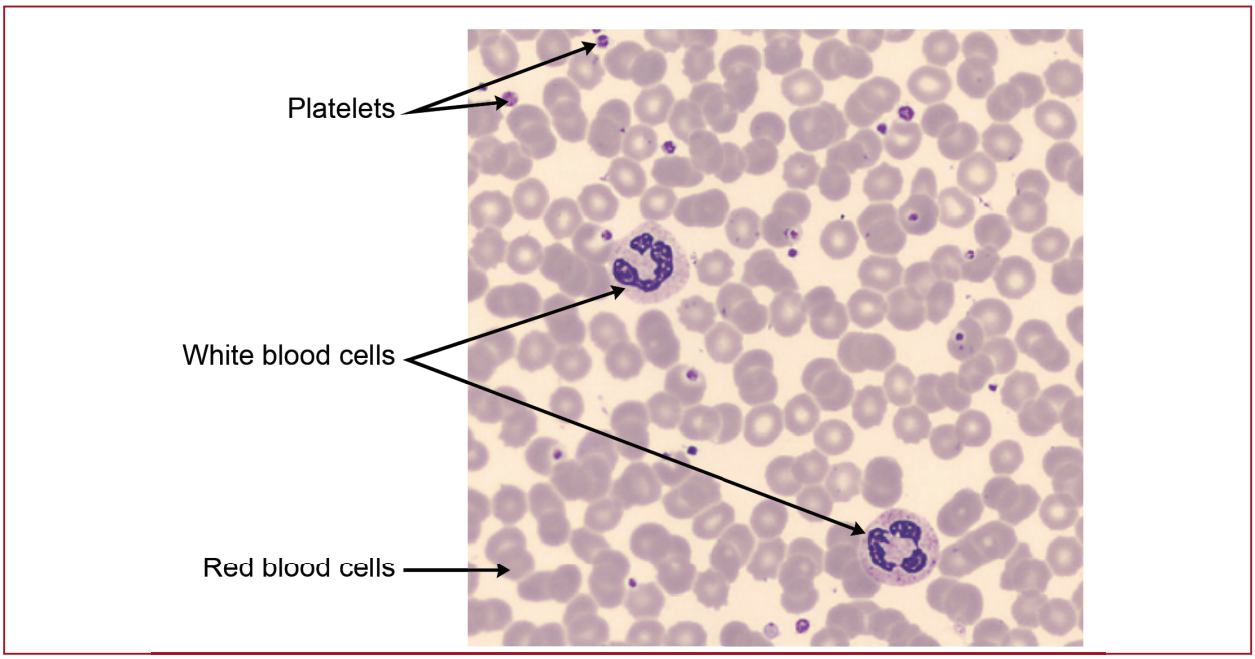
Haematocrit (Hct) is a measure of the number of red cells found in the blood, stated as a percentage of the total blood volume. The normal range is between 43 and 49% in men and between 37 and 43% in women.

Table 1. Properties of the Main Components of Blood

Properties	Red Blood Cells	White Blood Cells	Platelets
Size	7 microns	7 – 20 microns	2 – 5 microns
Survival	120 days	Hours – few days	5 – 9 days
Normal ranges*	4.5 – 5.8 million	5,000 – 10,000	150,000 – 400,000
Function	Transport of O_2	Immune response, fight infection	Clotting

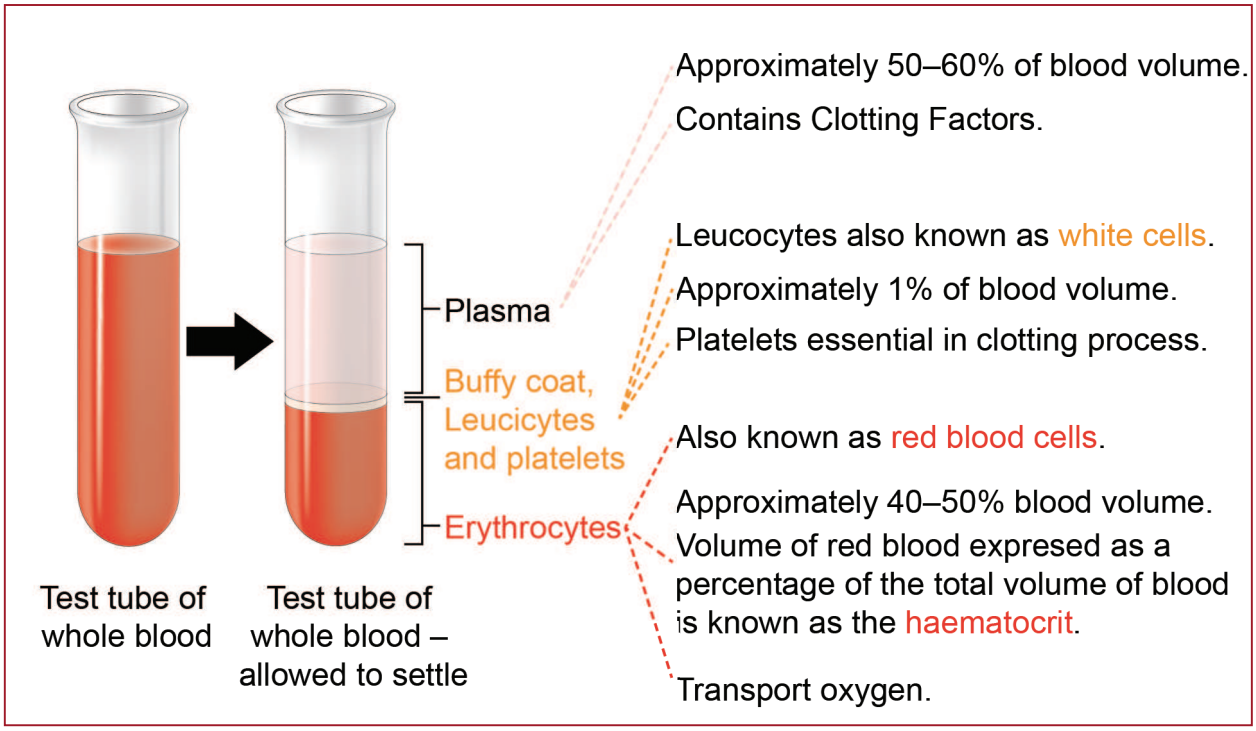
*Normal ranges will vary according to age and gender and also depending on the technology used to measure the cells.

Figure 1. Red Blood Cells, White Blood Cells and Platelets



Because the components of blood have different densities, if they are allowed to settle in a test tube or spun in a centrifuge, they will separate according to their densities (Figure 2).

Figure 2. Blood Separated into its Constituent Parts



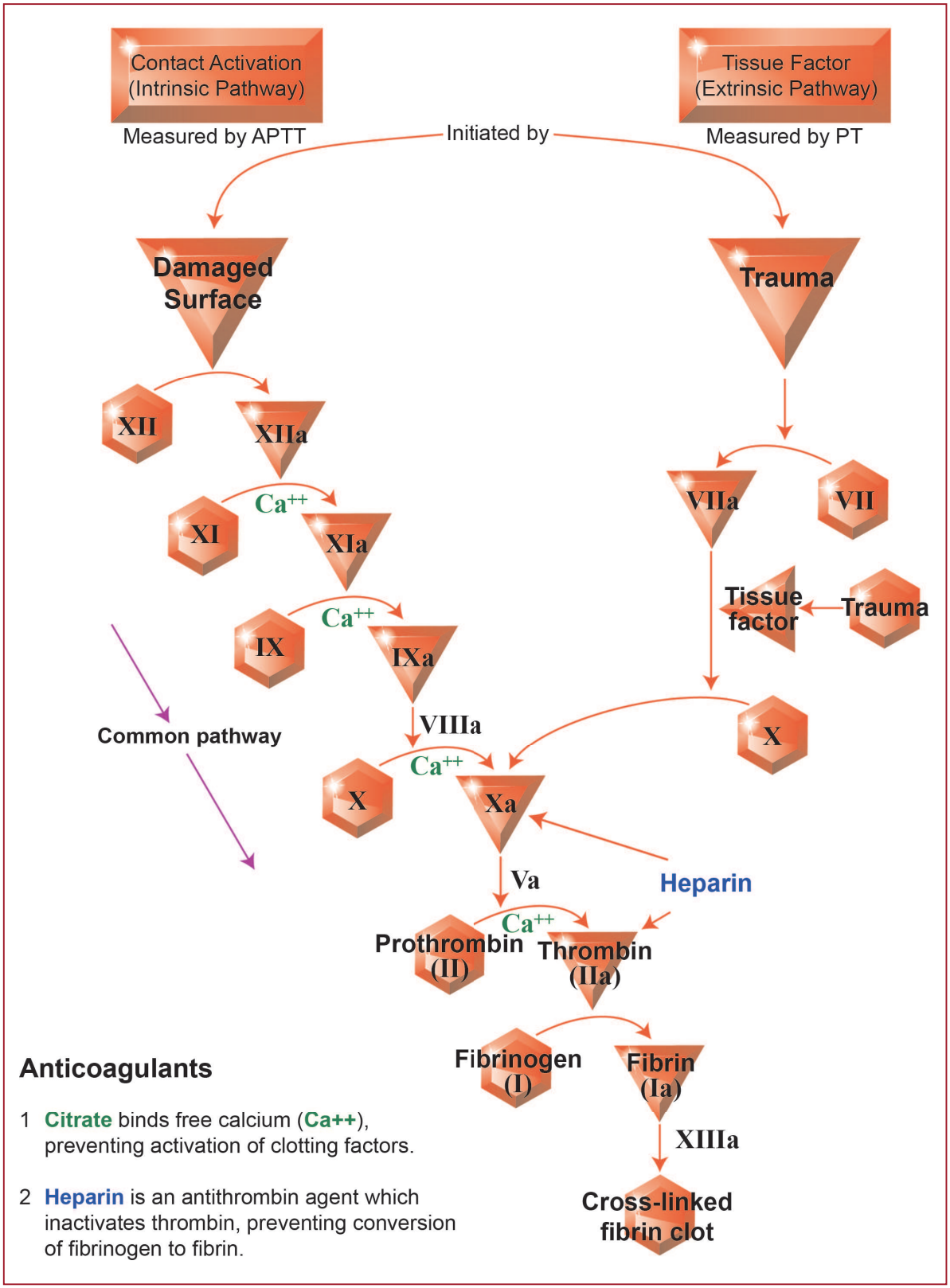
3.3 Coagulation

The clotting cascade is initiated by either the intrinsic or extrinsic pathway both leading
to a series of coagulation events. The intrinsic pathway is initiated when blood comes into contact with a foreign (non-endothelial) surface such as tissue grafts or artificial heart valves, or when blood is removed from the body. The extrinsic pathway is normally activated by an external tissue injury such as a cut or ruptured vessel. Regardless of the origin, an amplification of the coagulation process leads to a common pathway where fibrinogen is converted to fibrin. During surgical procedures both the intrinsic and extrinsic pathway are stimulated.

Coagulation tests

- The APTT is a test of the intrinsic pathway of coagulation. (Activated Partial Thromboplastin Time (APTT, KCCT, PTTK, KPTT, PTT)). All the above abbreviations refer to the same test and terminology varies between laboratories.
- The PT tests the extrinsic pathway of coagulation (One Stage Prothrombin Time (OSPT, PT)).
- TEG®/ROTEM® are tests of whole blood coagulation measuring the viscoelastic properties of the developing blood clot. These tests can be performed near to the patient i.e. they are Point of Care Tests (POCT).
- Platelet function tests (e.g. Platelet mapping™, Multiplate®, Verifynow®) measure the effect of platelet inhibitory drugs on platelet function.

Figure 3. The Coagulation Cascade



(Adapted from the American Association for Clinical Chemistry[1])

3.4 Allogeneic (Donor) Blood Components

All blood components in the UK are collected from blood donors who are unpaid volunteers. They are very carefully selected and tested to make sure that the blood they donate is as safe as possible. Compared to other everyday risks, the likelihood of getting an infection from a blood transfusion is very low. All units supplied in the UK are leucodepleted (white blood cells removed) and have been since 1999 as a precaution against variant Creutzfeldt-Jakob Disease (vCJD), with the exception of Granulocytes, which are the white blood cells. Table 2 lists the blood components available for clinical use.

Table 2. Allogeneic (Donor) Blood Components

Component	Volume	Storage	Clinical indications in the surgical setting
Red cells	220-340ml	Designated temperature controlled fridge 2-6ºC. Shelf life: 35 days.	To raise the oxygen-carrying capacity of the blood when it is symptomatically reduced due to red cell loss or reduced red cell production.
Platelets	Apheresis ~199ml Pooled ~300ml	Temperature controlled 'room temperature' (20-24ºC) - gentle agitation to promote gaseous exchange. Shelf Life: 5-7 days.	The prevention and treatment of bleeding due to: • Thrombocytopenia associated with large volume blood transfusions. • Consumption due to disseminated intravascular coagulation (DIC), major surgery.
Fresh frozen plasma* *Patients born on or after 1 January 1996 should only receive plasma sourced from countries with a low risk of vCJD.	~274ml	Designated temperature controlled freezer <-25ºC. Shelf life: 36 months (24 hours at 4ºC after thawing).	• Clinically abnormal haemostasis following massive blood transfusion or major surgery. • Multiple coagulation factor deficiencies and disseminated intravascular coagulation (DIC). • Haemostatic defects associated with liver disease if bleeding/invasive procedure.
Cryo-precipitate	Single ~43ml Pooled ~189ml	Designated temperature controlled freezer <-25ºC. Shelf life: 36 months (use within 4 hours of thawing, do not refrigerate).	Bleeding associated with hypofibrinogenaemia. This most commonly occurs in: • DIC • massive transfusion • advanced liver disease.
Granulocytes	Single ~40-70ml Pooled ~207ml	Temperature controlled 'room temperature' (20-24ºC). Shelf-life: 24 hours.	Patients with/at high risk of developing life-threatening bacterial or fungal infection secondary to neutropenia caused by bone marrow failure or neutrophil dysfunction.

3.5 Risks of Allogeneic (Donor) Transfusion

It is rare for someone to develop a viral infection from a blood transfusion, as the blood services use strict testing processes, however there will always be a small risk of this.

. The risk of getting vCJD from a blood transfusion is extremely low with a single blood transfusion, but the risk of any infection will increase with additional blood transfusions. . One of the biggest risks is from getting the “wrong blood” as evidenced by the Serious Hazards of Transfusion (SHOT) annual reports[2].

Blood and blood components must always be stored under controlled storage conditions in designated fridges, freezers, and agitators.

3.6 Allogeneic (Donor) Blood Products

Human Albumin 4.5%

4.5% human albumin is iso-oncotic with human plasma. It is usually supplied in a 400ml bottle which is stored at room temperature. The dosage should reflect circulating blood volume, rather than measures of albumin levels, and will vary according to patient size and the severity of the illness or fluid/protein losses. It is usually administered through a standard infusion set at rates of 5-15ml per minute, although this varies according to clinical need.

There is no firm evidence that the use of colloids, including albumin, is advantageous over the use of balanced crystalloid solutions for fluid resuscitation in patients with trauma, burns or following surgery[3].

Simply raising a patient’s albumin level does not improve outcome and other fluids may be effective for raising blood pressure: e.g. balanced crystalloid solutions

Human Albumin 20%

20% albumin has an oncotic pressure approximately 3-4 times higher than that of normal human plasma and infusion will therefore expand plasma volume by drawing in extravascular fluid. It is supplied in 100ml bottles and again is infused through a standard infusion set at rates of 1-2ml per minute.

20% albumin solutions are used in the management of:

- Hypoproteinaemic oedema associated with nephrotic syndrome (diuretic resistant oedema)
- Ascites in liver disease

Immunoglobulin Products

Immunoglobulins are the antibodies produced by B-lymphocytes in response to infection. Immunoglobulins are important for the correct functioning of the immune system, fighting bacterial infections, neutralising viruses and activating the complement systems.

Fractionated Plasma Derivatives

Fractionated plasma derivatives such as prothrombin complex concentrate (combined Factor II, VII, IX, X concentrates), fibrinogen concentrate and other single Factor concentrates (e.g. Factor VIII or IX) are used in the management of both hereditary and acquired clotting disorders.

3.7 Recombinant Therapies

Recombinant Clotting Factors

Recombinant clotting Factors VIII and IX are used as a treatment for people with Haemophilia A and B, respectively.

Allogeneic blood products fall under the Human Medicines Regulations (2012), are classed as medicines and must be prescribed.

Allogeneic blood components do not fall under these regulations, are not classed as medicines and do not need to be prescribed, but must be authorised by an appropriately qualified healthcare professional.

Key Points

- Red cells are the heaviest component of blood and it is this property that allows the separation of washed red cells from the waste products in ICS.
- Heparin and citrate both inhibit coagulation and this allows for blood to be collected without clotting.
- Allogeneic blood and blood components are extremely safe and the greatest risk is in giving the wrong blood.

References

1. AnaesthesiaUK. Coagulation – classical model (2005). *http://www.frca.co.uk/article.aspx?articleid=100096*
2. Serious Hazards of Transfusion (1996 – 2016) Annual Reports *www.shotuk.org*
3. Perel P, Roberts I, Ker K. Colloids versus crystalloids for fluid resuscitation in critically ill patients. Cochrane Database Syst Rev. 2013 Feb; 28;2:CD000567

Further Reading

- Hoffbrand's Essential Haematology (Essentials), V. Hoffbrand and P Moss (2015) *(ISBN-13:978-1118408674)*
- ABC of Transfusion (ABC Series), Marcela Contreras (2009) *(ISBN 10-1405156465)*
- Handbook of Transfusion Medicine, 5th Edition *ed D Norfolk (2013) (ISBN 9780117068469)*

Self-Directed Learning

What are the normal ranges for Haemoglobin (Hb), Haematocrit (Hct), and platelets in your hospital?

What are the normal ranges for Prothrombin Time (PT), Activated Partial Thromboplastin Time (APTT) and Fibrinogen in your hospital?

What allogeneic blood components are available from your blood transfusion laboratory?

What allogeneic blood products are available in your hospital?