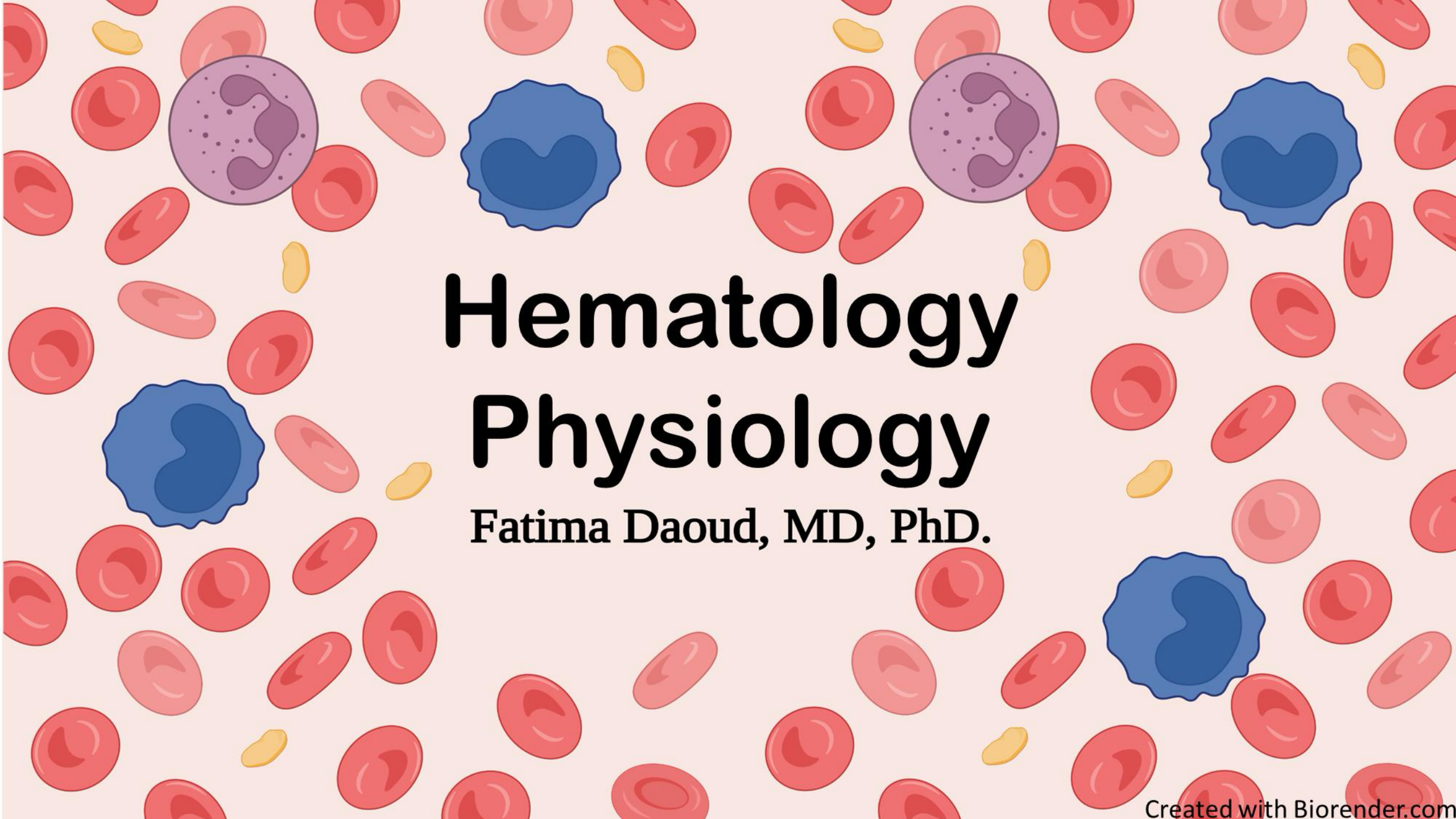

Hematology Physiology

Fatima Daoud, MD, PhD.

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Reference books:

1. **Hall, John, E. and Michael E. Hall. Guyton and Hall Textbook of Medical Physiology (14th Edition).**
2. Lauralee Sherwood. Human Physiology: From Cells To Systems (9th Edition).
3. Gerard J. Tortora and Bryan Derrickson. Principles Of Human Anatomy & Physiology (15th Edition)

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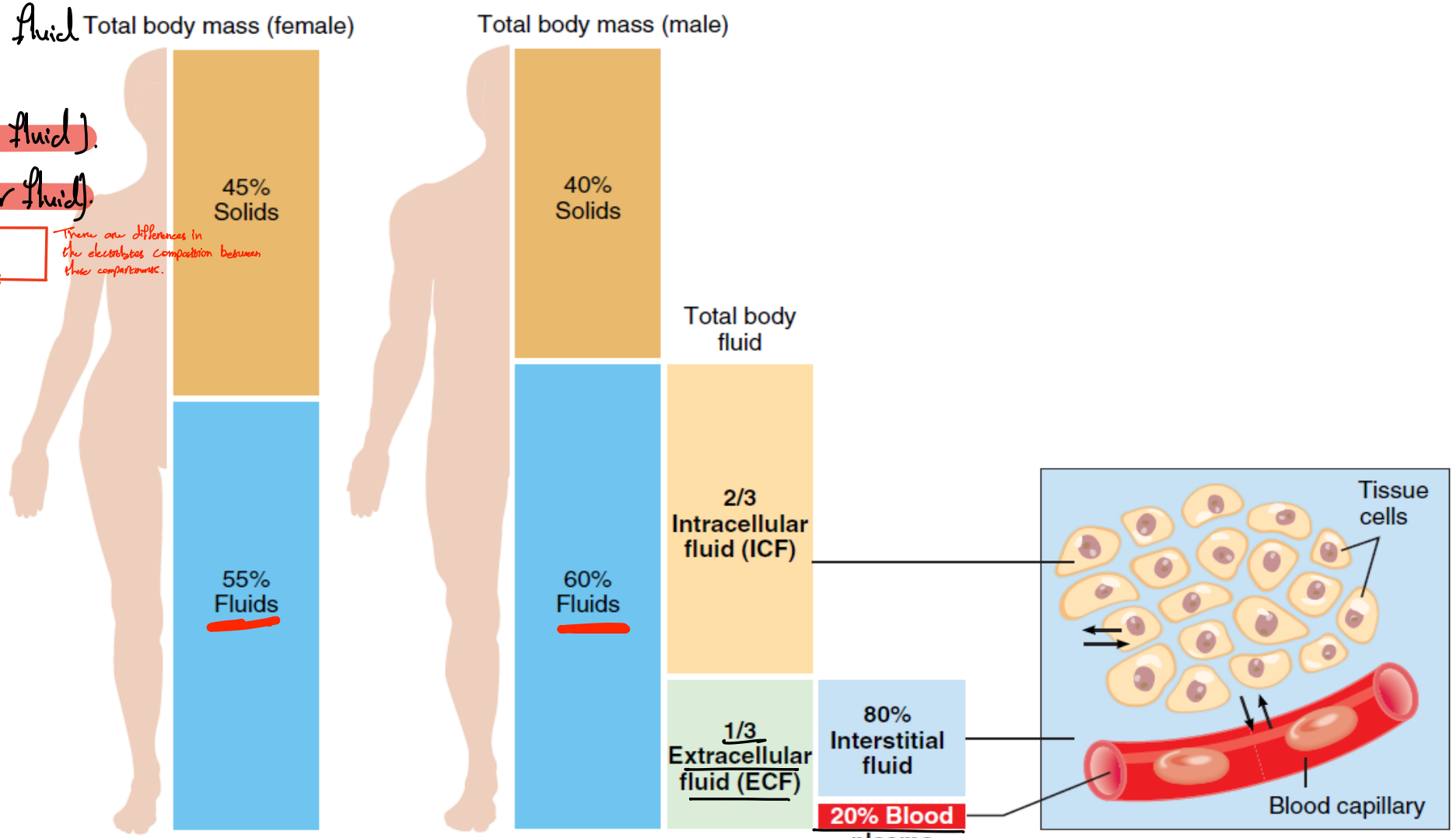
Hematology Body Fluids

we divide body fluid compartments into :-

* ICF (Intracellular fluid).
* ECF (Extra cellular fluid).
  - plasma
  - interstitial fluid

There are differences in the electrolytes composition between these compartments.

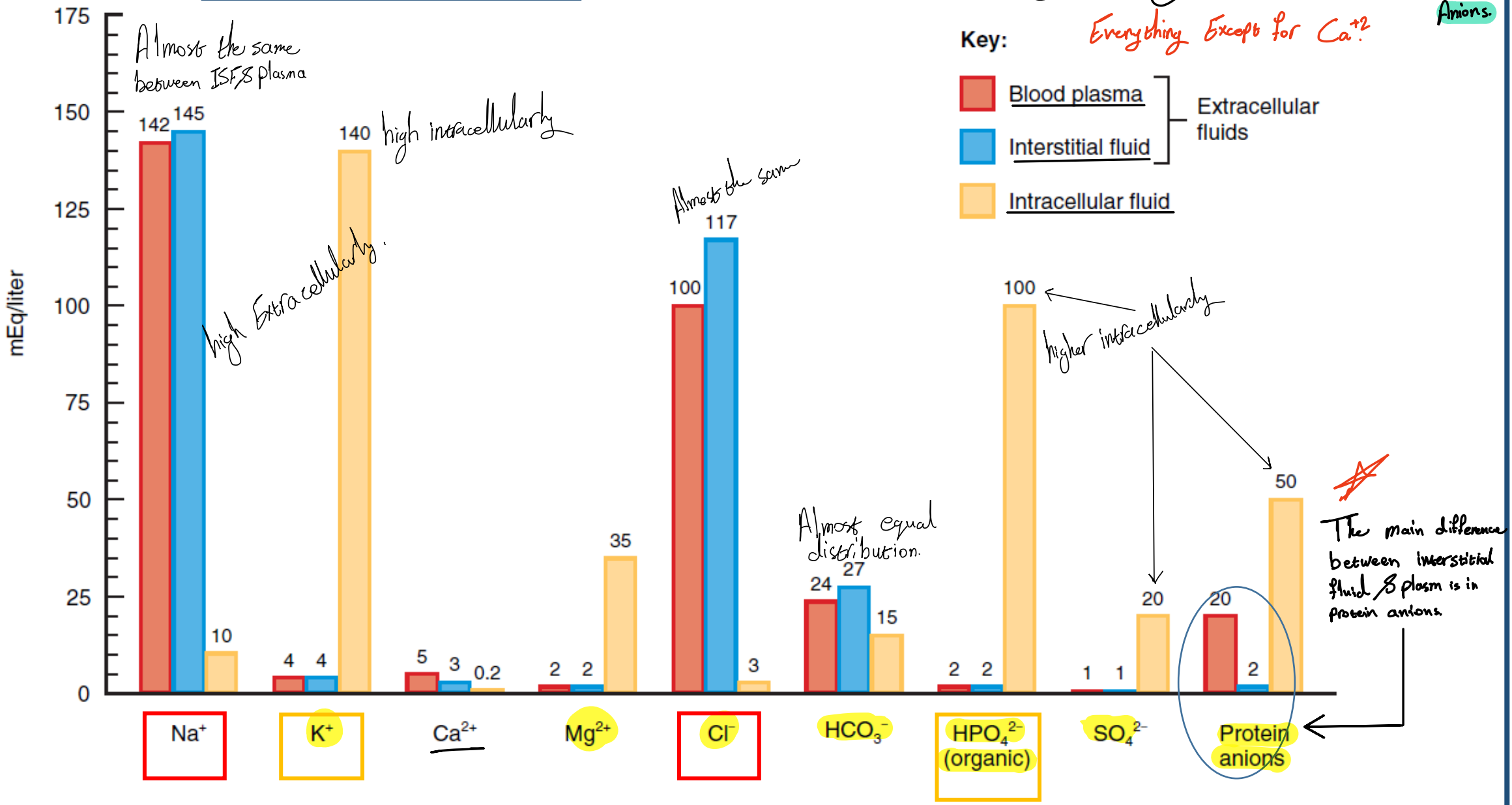


(a) Distribution of body solids and fluids in average lean adult female and male

Hematology | Body Fluids

The main difference between intracellular compartments & Extracellular compartments is in :- ① Na^+ ② K^+ ③ Mg^{+2} ④ Cl^- ⑤ HPO_4^{-2} ⑥ SO_4^{-2} ⑦ Protein Anions.

Everything Except for Ca^{+2}



Hematology

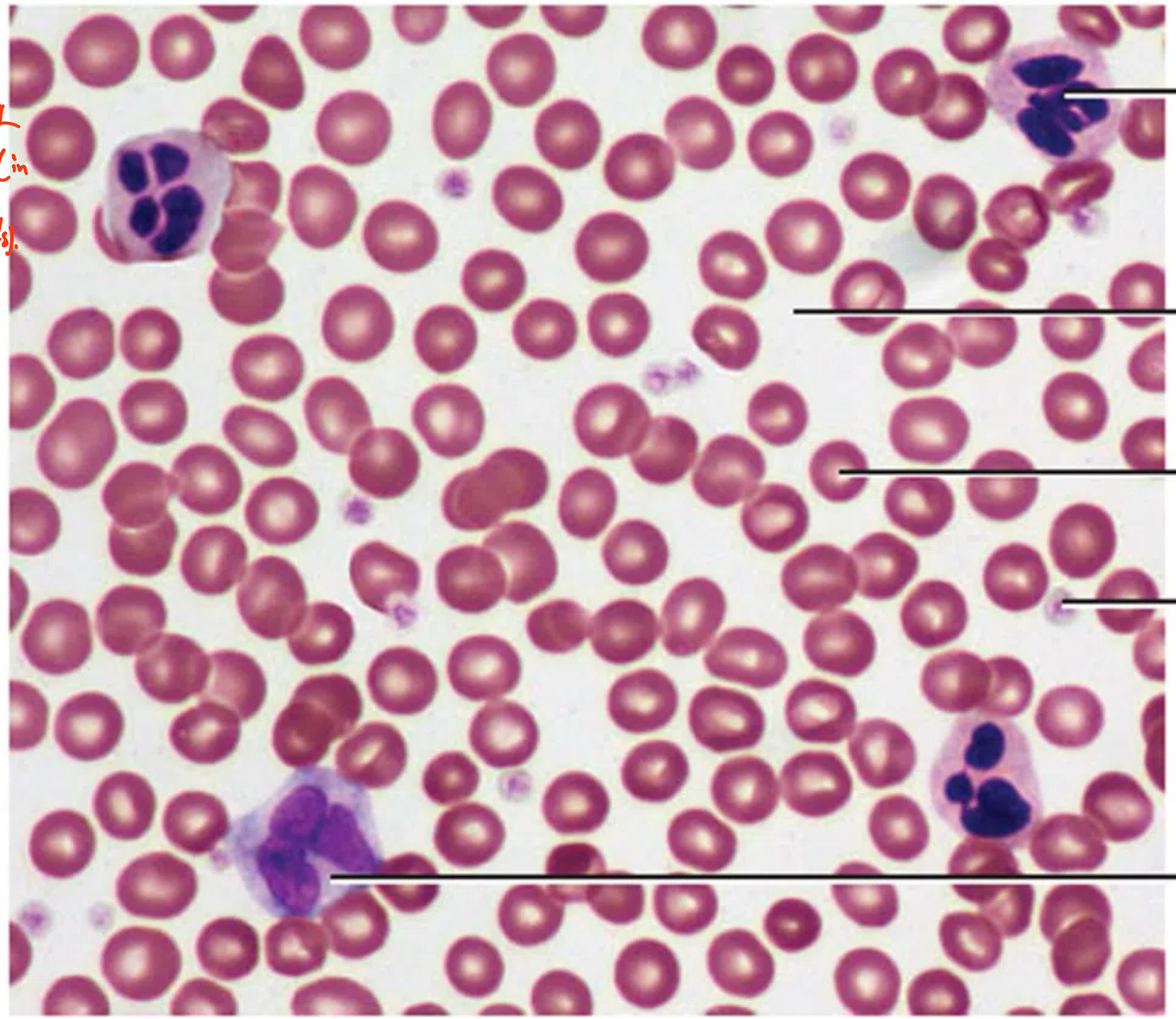
Blood: general characteristics

- The average blood volume of adults is about **7–8%** of body weight, or about 5 liters.
- Blood is connective tissue.
- Blood is denser and more viscous (thicker) than water.
- The temperature of blood is 38°C.
- Slightly alkaline pH ranging from 7.35 to 7.45 (average = 7.4).
- The color saturated (O_2)→ bright red

  unsaturated (O_2) → dark red

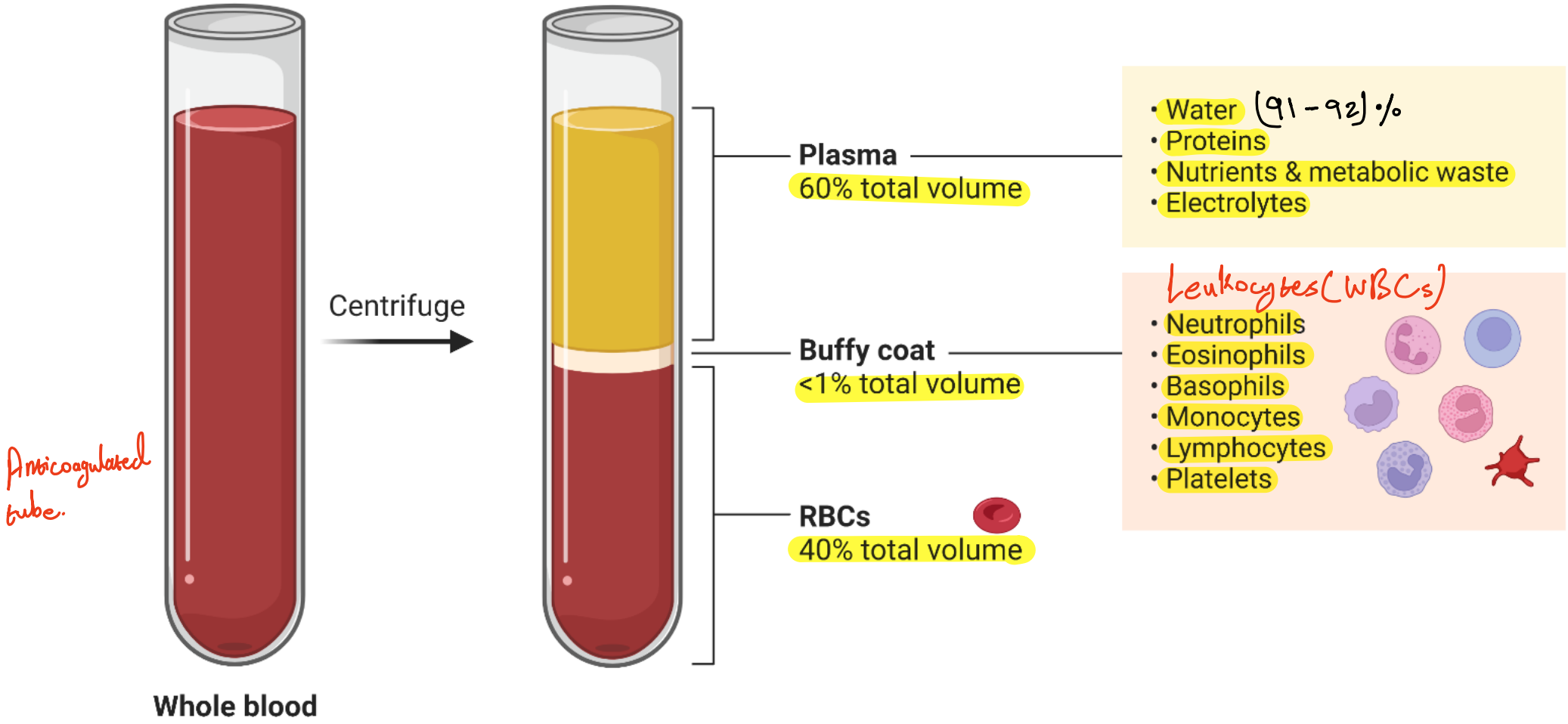
Blood Smear

This an importante aproach for dignosing Cancers, & Aniemia (in the past, now we use more automated methods).



Hematology

Blood and its components



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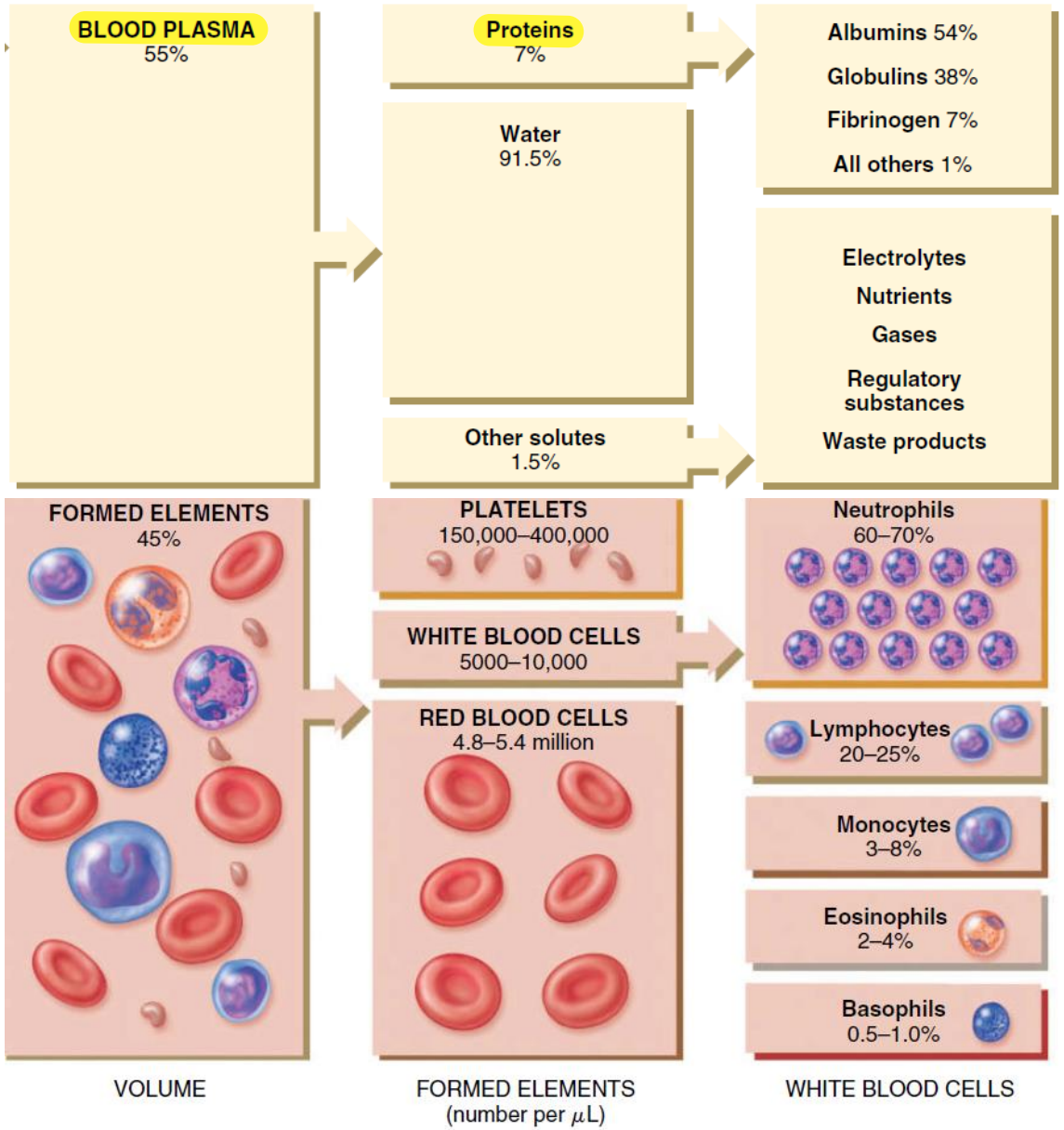
Hematology

Blood and its components



are major difference between plasma & interstitial fluid

Hematology — Plasma Protein

1. Establishment of colloid osmotic pressure.

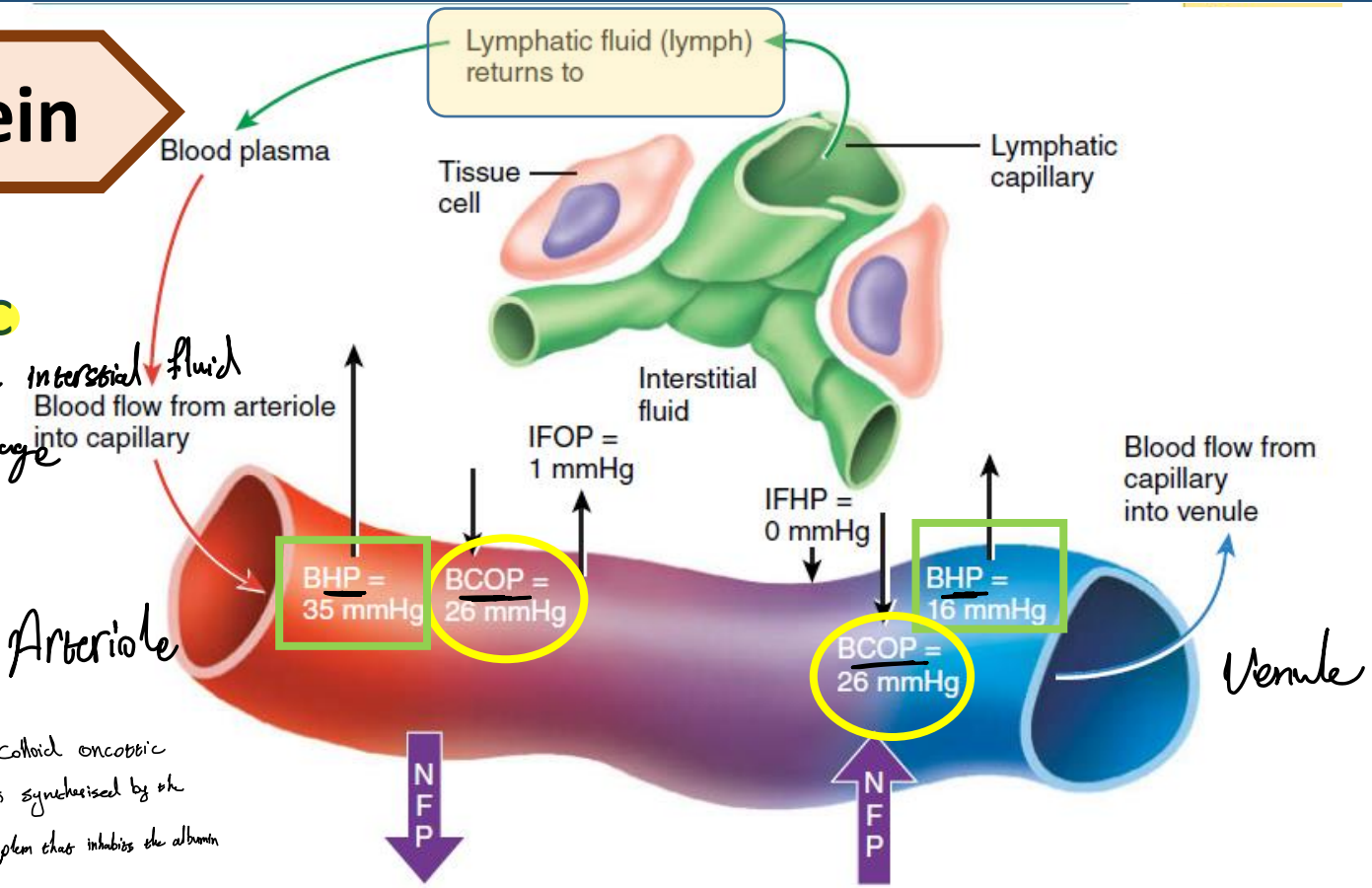
Drive the movements of plasma from the interstitial fluid into the plasma and prevents the leakage of fluid out of vascular system.

Key:

BHP = Blood hydrostatic pressure
IFHP = Interstitial fluid hydrostatic pressure
BCOP = Blood colloid osmotic pressure
IFOP = Interstitial fluid osmotic pressure
NFP = Net filtration pressure

Blood hydrostatic pressure pushes fluid out of capillaries (filtration)

Blood colloid osmotic pressure pulls fluid into capillaries (reabsorption)



Arteriole

Venule

* one of the main drivers of colloid oncotic pressure is albumin which is synthesised by the liver, so if there is any liver problem that inhabits the albumin synthesis. this is going to cause edema.

* plasma proteins works as a transporters for lipid soluble substance.

	Net filtration at arterial end of capillaries (20 liters per day)		Net reabsorption at venous end of capillaries (17 liters per day)
Net filtration pressure (NFP)	(BHP + IFOP)	–	(BCOP + IFHP)
	Pressures promoting filtration		Pressures promoting reabsorption
	Arterial end		**Venous end**
	NFP = (35 + 1) – (26 + 0) = 10 mmHg		NFP = (16 + 1) – (26 + 0) = –9 mmHg
Result	Net filtration		Net reabsorption

3 Liters. absorbed back by lymphatic system to vascular circulation.

Hematology — Plasma Protein

2. Responsible for plasma's capacity buffer changes in pH.

Albumin (Synthesised from liver)

Nonspecifically binds substances that are poorly soluble in plasma (bilirubin & fatty acids)

Fibrinogen

Is an inactive precursor for a clot's fibrin meshwork

Globulins

α & β

- Specifically bind poorly water-soluble substances (thyroid hormone, cholesterol, and iron).
- Involved in blood-clotting.
- Angiotensinogen.

γ

Antibodies/ immunoglobulins.
Body's defense mechanism.

[Immunity]

Hematology

Principle roles of the blood

Transportation	Respiratory gases, nutrients, hormones, and metabolic wastes
Regulation	Acid–base balance (buffer changes in pH), heat distribution (Vasodilation. Vasoconstriction.), and fluid balance (through osmolarity).
Protection	Immune defense and prevention of blood loss

Hematology

Hemopoiesis (formation of blood cells)

Early fetal life

Occurs in the yolk sac of an embryo and later in the liver, spleen, thymus, and lymph nodes of a fetus.

last gestational months- death

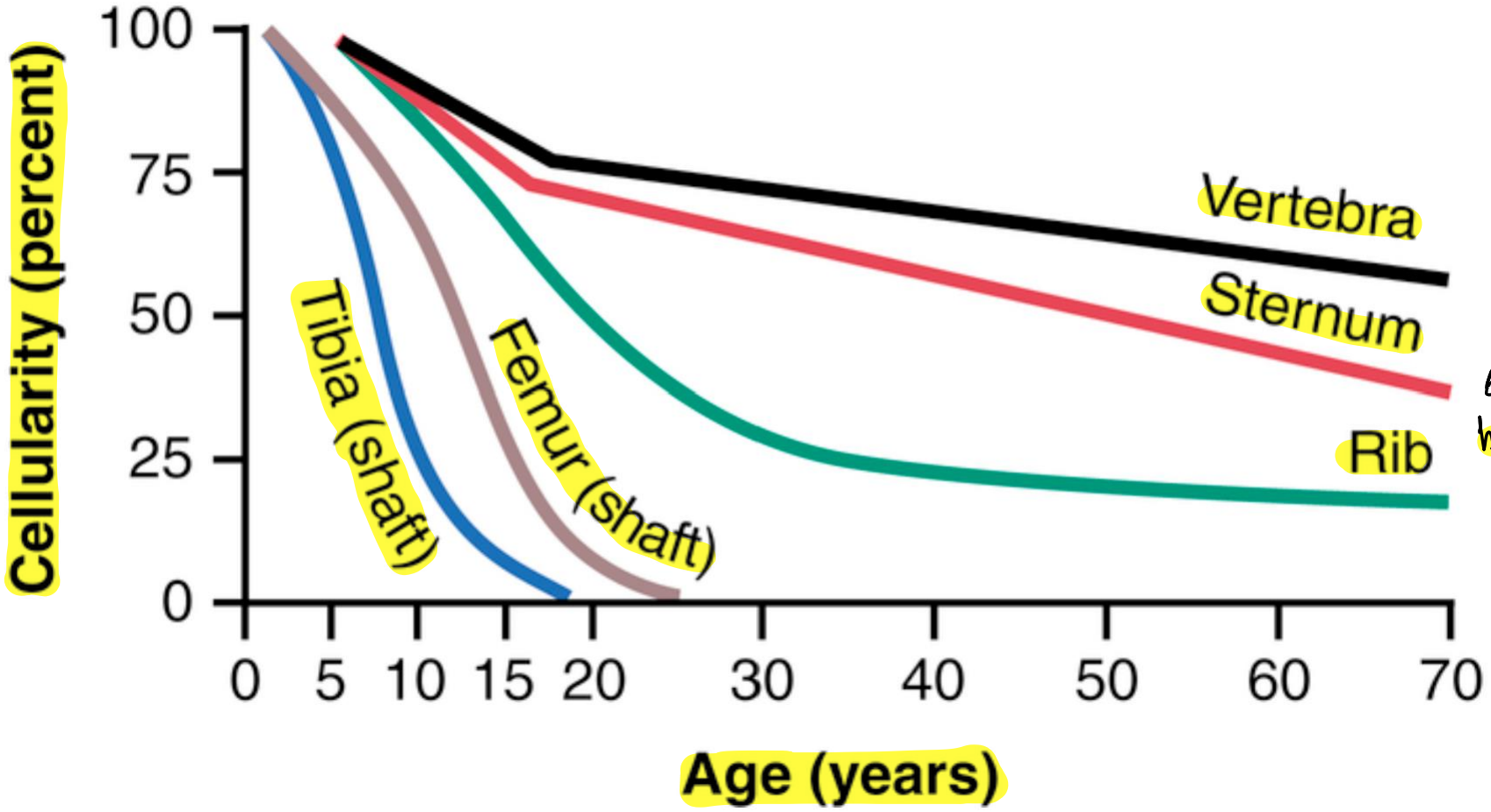
Red bone marrow becomes the primary site of hemopoiesis in the, and continues as the source of blood cells after birth and throughout life.

*Hemopoiesis' location throughout life:-

Hematology

Hemopoiesis (formation of blood cells)

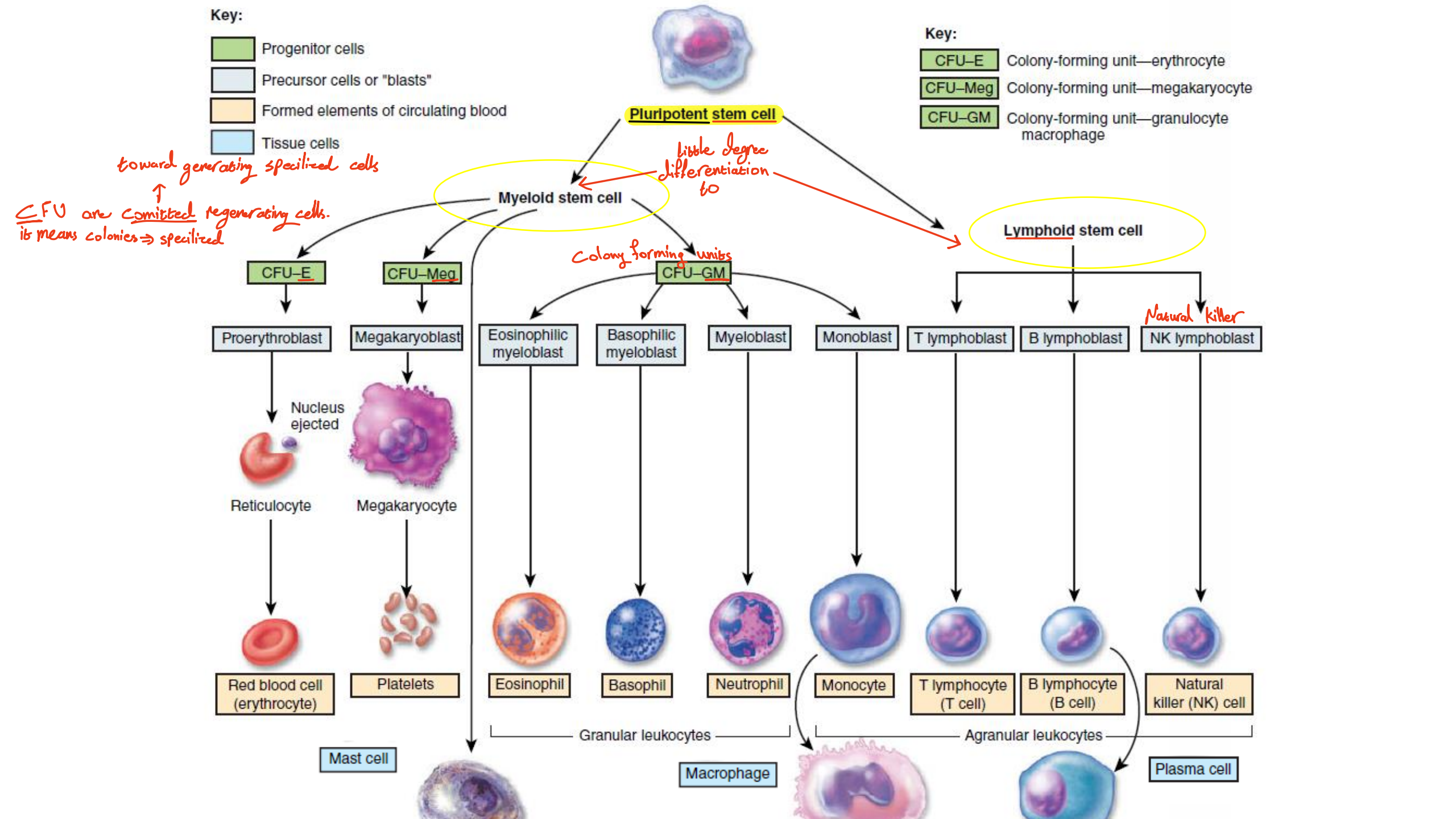
Red bone Marrow ⟶ located in the core of bones, but which bones ?! it depends on age.



As we are getting older the Hemopoiesis process shifts from being happening mainly at the shafts of long bones towards their ends.

As we are hitting 20 Y.O. the hemopoiesis process becom happening mainly at flat bones.

it decreases with age.


Key:
Progenitor cells
Precursor cells or "blasts"
Formed elements of circulating blood
Tissue cells
toward generating specilized cells
CFU are committed regenerating cells.
its means colonies ⇒ specilized
Key:
CFU–E Colony-forming unit—erythrocyte
CFU–Meg Colony-forming unit—megakaryocyte
CFU–GM Colony-forming unit—granulocyte macrophage
Pluripotent stem cell
little degree differentiation to
Myeloid stem cell
Lymphoid stem cell
Colony forming units
CFU–E
CFU–Meg
CFU–GM
Natural killer
Proerythroblast
Megakaryoblast
Eosinophilic myeloblast
Basophilic myeloblast
Myeloblast
Monoblast
T lymphoblast
B lymphoblast
NK lymphoblast
Nucleus ejected
Reticulocyte
Megakaryocyte
Red blood cell (erythrocyte)
Platelets
Eosinophil
Basophil
Neutrophil
Monocyte
T lymphocyte (T cell)
B lymphocyte (B cell)
Natural killer (NK) cell
Granular leukocytes
Agranular leukocytes
Mast cell
Macrophage
Plasma cell

Hemopoiesis (formation of blood cells)

- ✓ **Myeloid stem cells**
  - Give rise to red blood cells, platelets, monocytes, neutrophils, eosinophils and basophils
- ✓ **Lymphoid stem cells** give rise to
  - Lymphocytes and natural killer cells

Hemopoiesis (formation of blood cells)

- **Stem cells in bone marrow**
  - Reproduce themselves
  - Proliferate and differentiate

- **Formed elements do not divide once they leave red bone marrow**
  - Exception is lymphocytes

They have already been a specific type of WBCs which normally don't divide under physiological conditions

Hematology

Hemopoiesis (Regulation)

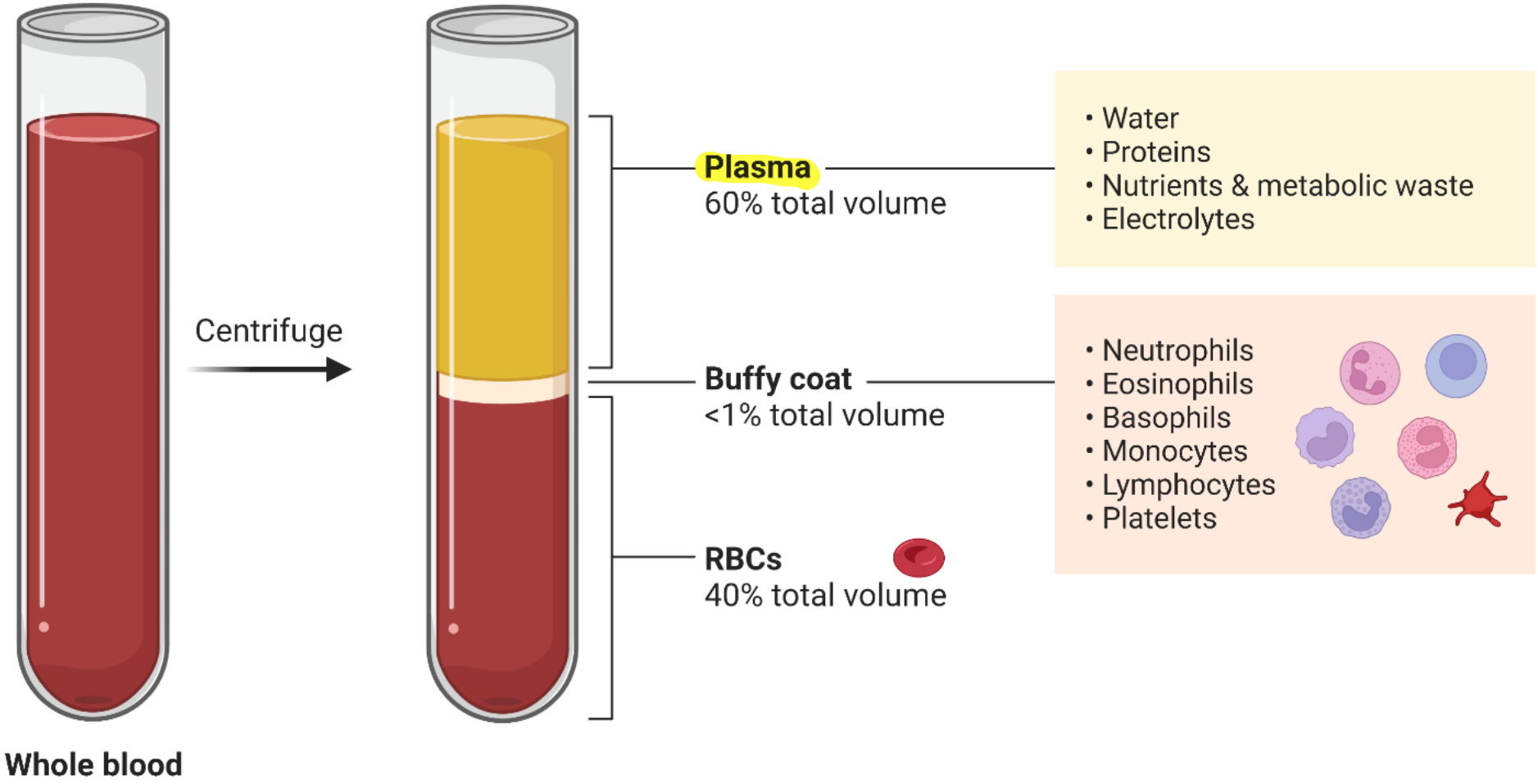
What causes stem cells to differentiate to a specific type of white blood cells ?: inducers. (Signals)/ sometimes called differentiation inducer.

- **Growth inducers**: regulate growth and reproduction of the different stem. One of the growth inducers is **interleukin-3**, promotes growth and reproduction of virtually all the different types of committed progenitor cells. (**GM-CSF**, **G-CSF**, and **M-CSF**)
- **Differentiation inducers**: Each of these differentiation inducers causes one type of committed stem cell to differentiate one or more steps toward a final adult blood cell.
- Others: **Erythropoietin** – RBCs, **Thrombopoietin** – platelets (Thrombocytes is the the other name).
- **Signals from outside the marrow match production to the body's needs**

Hematology

Packed Red Cell Volume

PCV is a laboratory test that is used to reflect the volume of RBC to the total blood volume
→ now it is automated.



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Hematology | Hematocrit

- **Hematocrit/ Packed Red Cell Volume**
- Adult males: 40–54% (avg = 45%).
- Adult females: 38–46% (avg = 42%)

more RBCs Volume in men.

memorise

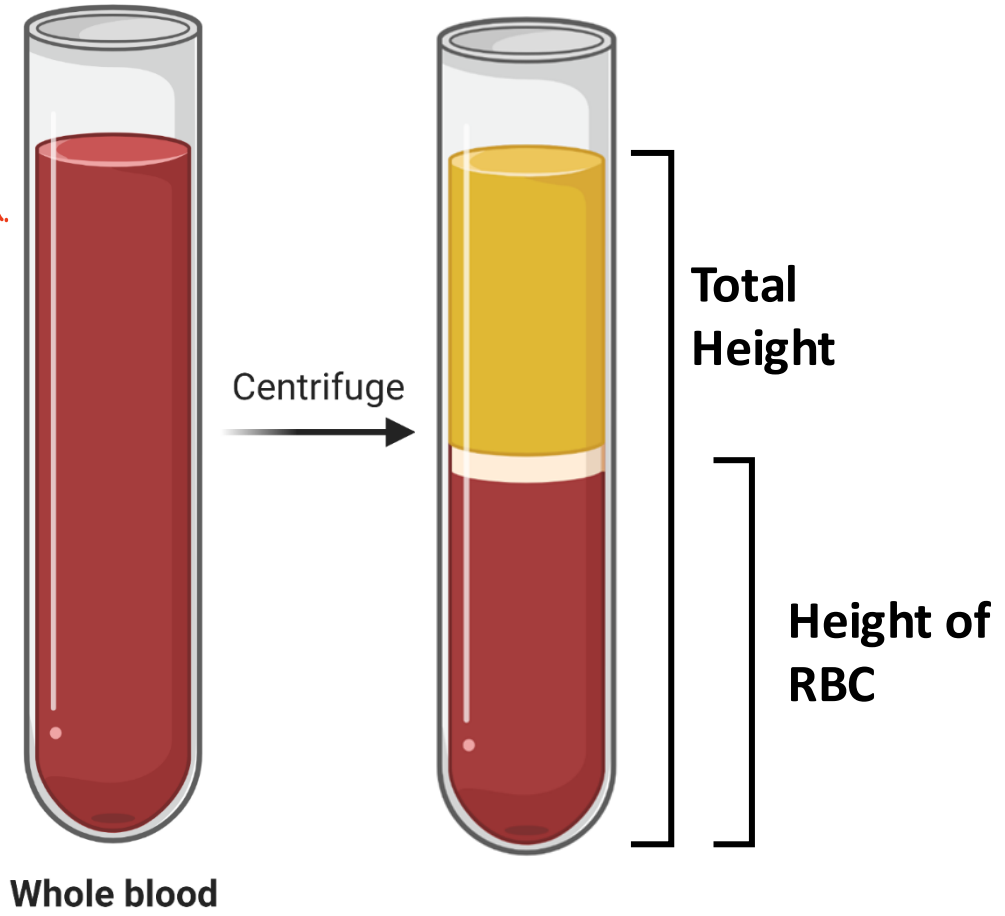
$$\text{Hematocrit} = \frac{\text{Height of RBCs}}{\text{Total height}} \times 100\%$$

→ Hematocrit is a ratio

no direct indication on ↑ number of RBCs.

* Ratio!!

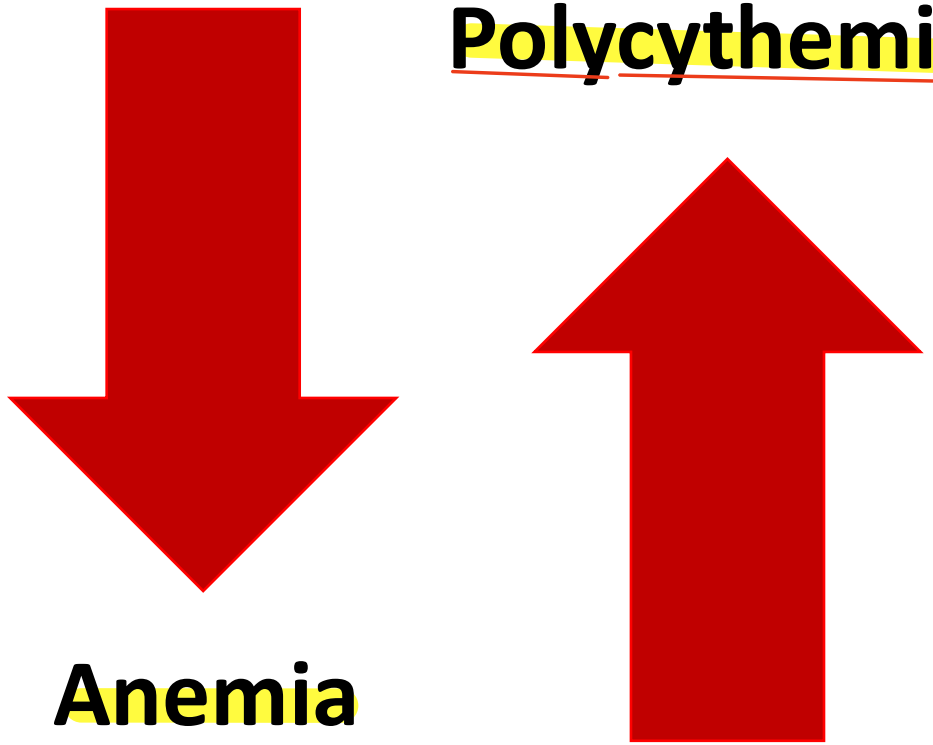
Why ?! Testosterone activates Hemopoiesis + menstrual cycle in women.



Hematology > Hematocrit

↑ (RBC)

Polycythemia



Anemia

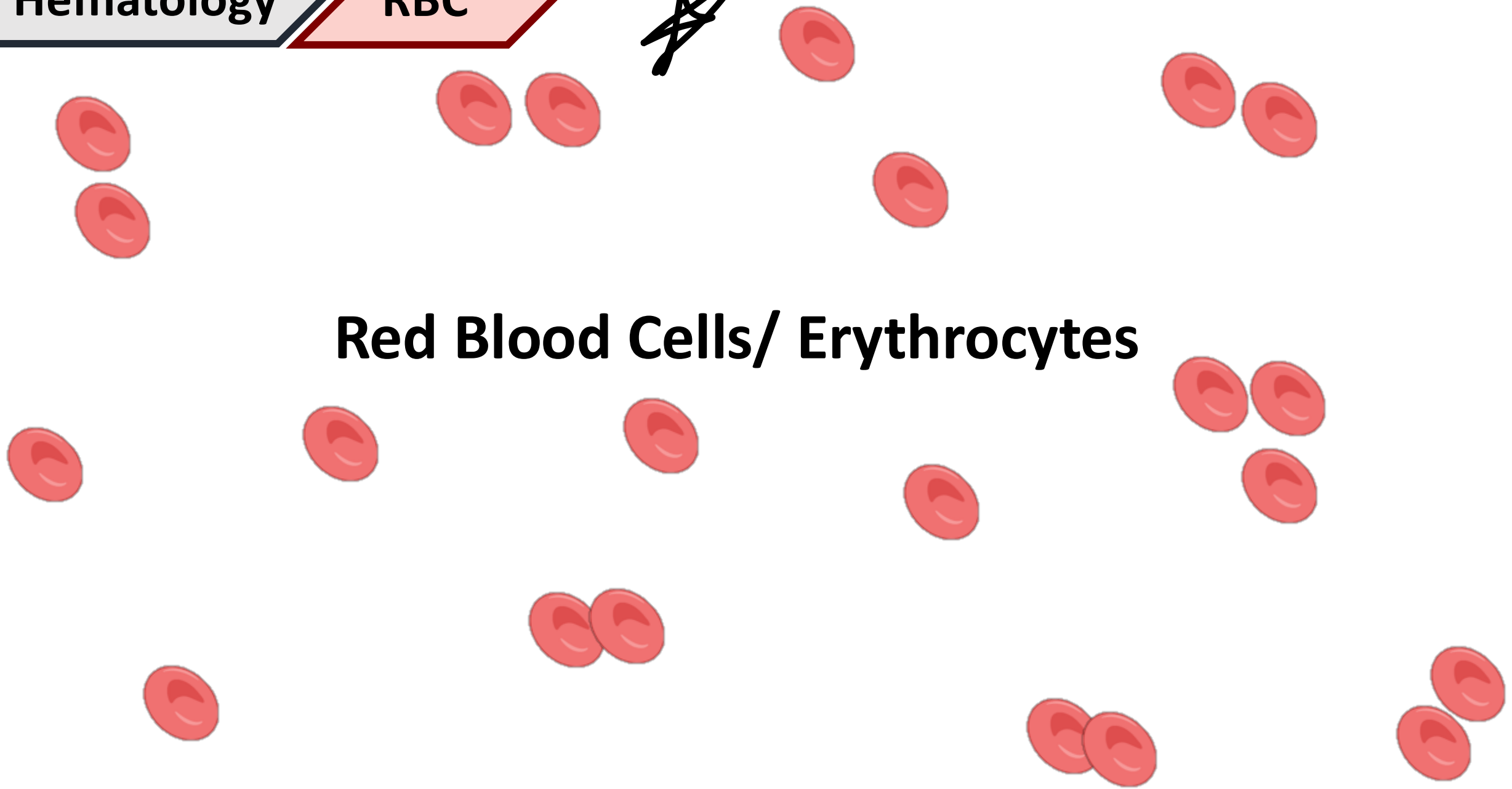
(↓ RBC)

* An increased hematocrit can reflect more RBCs.
  السبب أعلى
* It can also reflect less plasma.
  الحجم أقل
* Clinical interpretation must distinguish the two.

Since each indicate a specific condition.

* increased hematocrit due to ↓ plasma ⇒ Hypovolemia (Dehydration)
* increased hematocrit due to ↑ RBCs ⇒ Polycythemia.

Hematology RBC

we reached Here.

Red Blood Cells/ Erythrocytes