BLOOD PHYSIOLOGY

COMPOSITION & FUNCTIONS OF THE BLOOD

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TEXTBOOK OF MEDICAL PHYSIOLOGY

GUYTON & HALL 13TH EDITION

Objectives

- **At the end of this lecture you should be able to:**

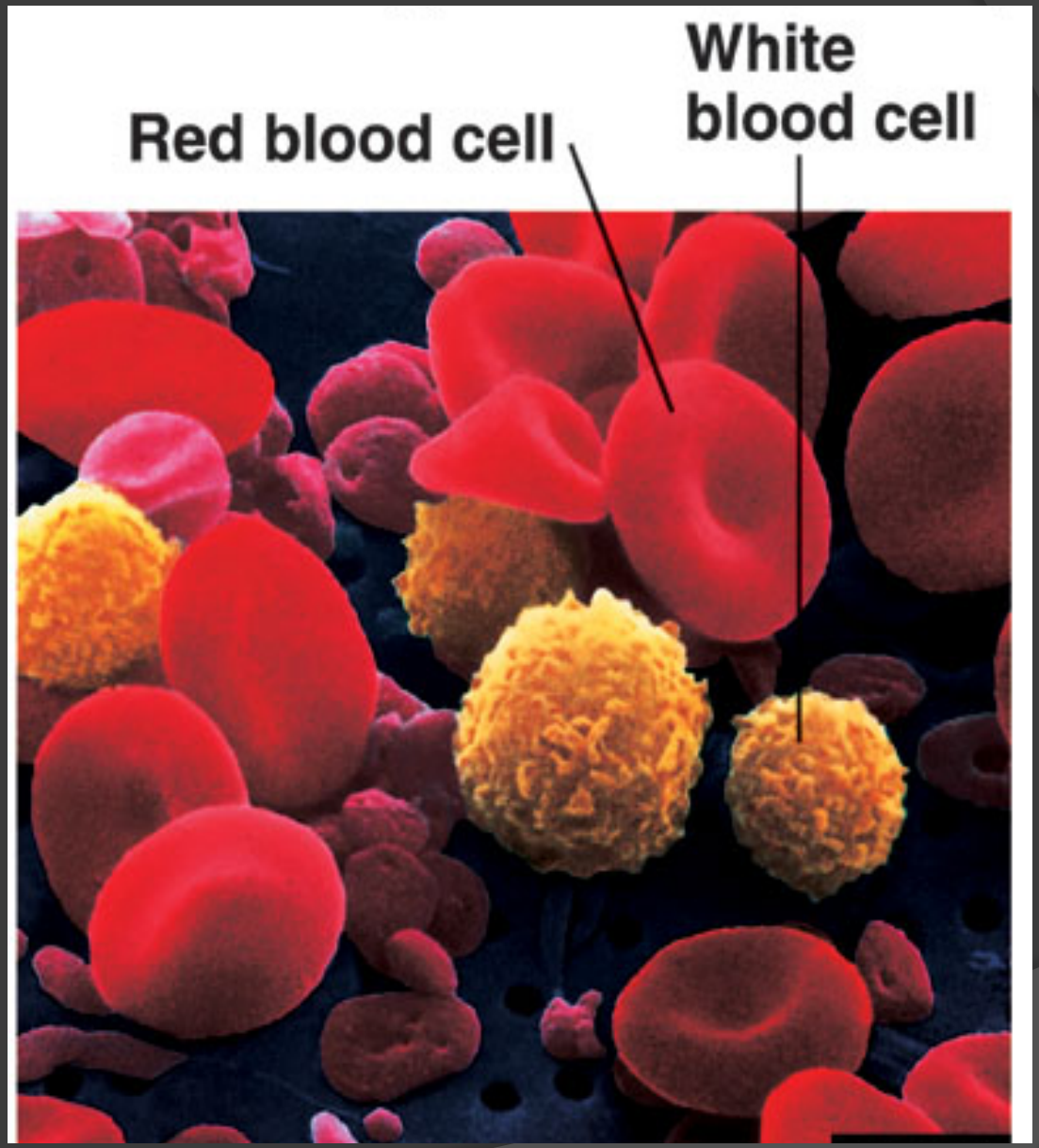
1. Describe Cellular & non-cellular components of blood.
2. Recognize functions of blood.
3. Define Erythropoiesis; leucopoiesis; thrombopoiesis.
4. Recognize sites of RBC formation at different developmental age.

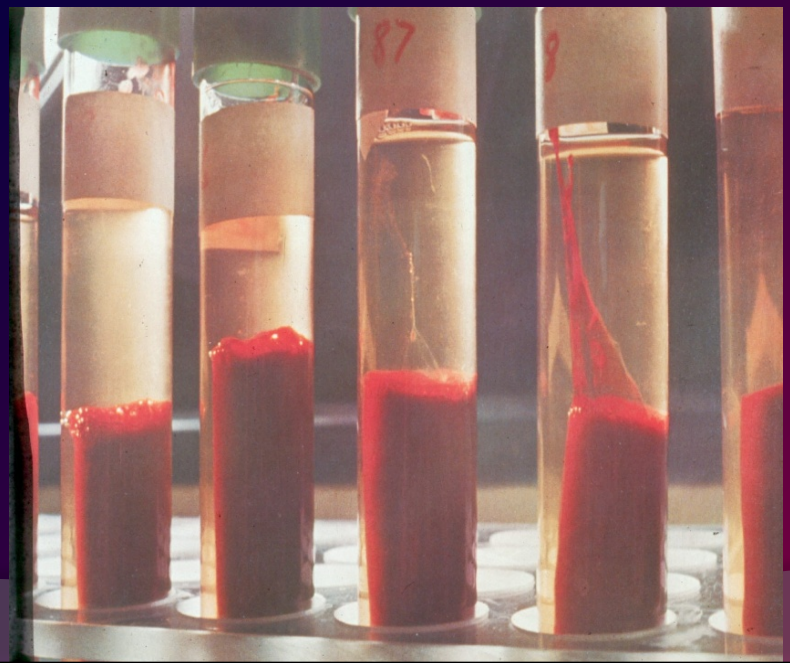
Objectives

cont…

5. Describe different stages of RBC differenation.
6. Describe features of RBC maturation.
7. Describe regulation of RBC production & erythropoietin hormone secretion in response to hypoxia.
8. Recognize clinical conditions associated with high level of erythropoitein in the blood.

Blood






dreamstime.com

FUNCTIONS OF BLOOD

1. **Transport**
   - O_2, CO_2
   - nutrient, hormones
   - waste product
2. **Homoeostasis.**

   - Regulation of body temperature, ECF pH
3. **Protecting against infections.**

   - White Blood Cells, Antibodies
4. **Blood clotting prevent blood loss.**

BLOOD COMPOSITION

1. **Cellular components:**

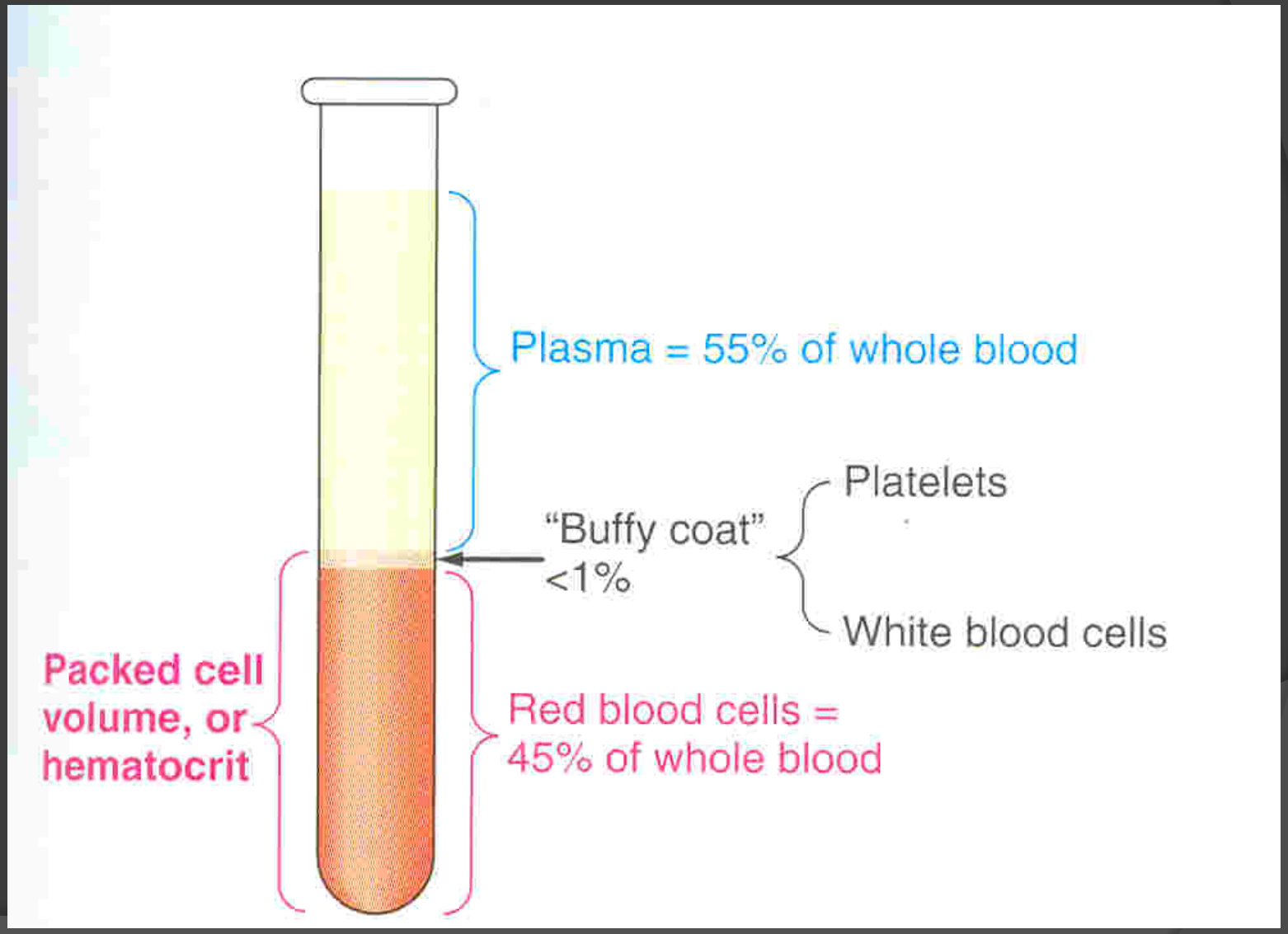
   - Red Blood Cells (Erythrocytes)
   - White Blood Cells (Leucocytes)
   - Platelets (Thrombocytes)

2. **Plasma**

   (*constituent of the ECF*)

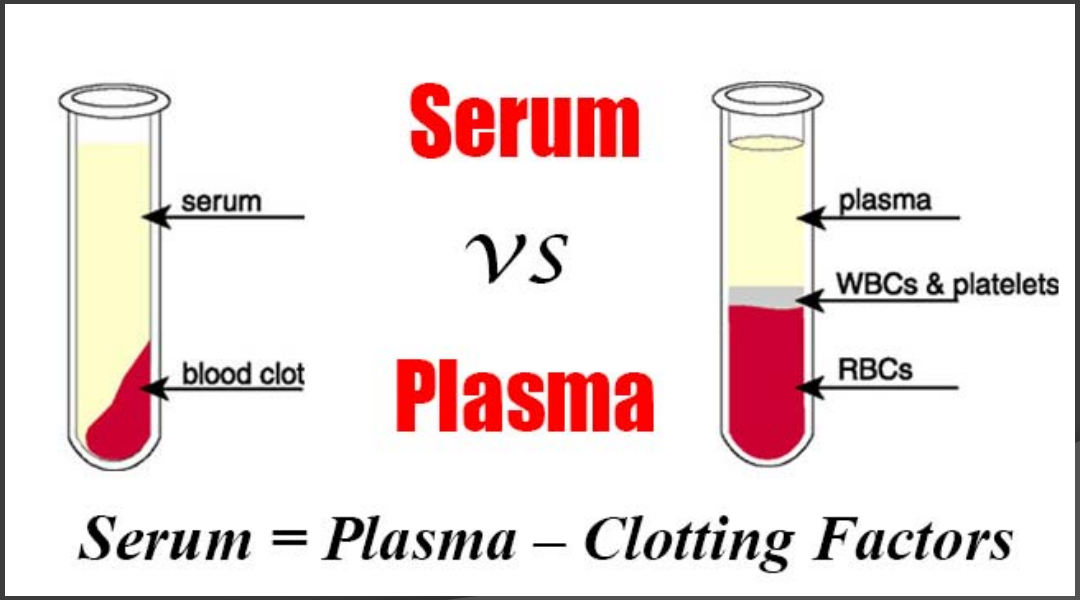
Components of Whole Blood

Blood Composition



- **Plasma** = whole blood minus cells.

- **Serum** = plasma minus clotting proteins.
  - If whole blood is allowed to clot.
  - Then, clot is removed, the remaining fluid is SERUM.
  - Thus, serum does not contain coagulation factors.



Constituents of plasma:

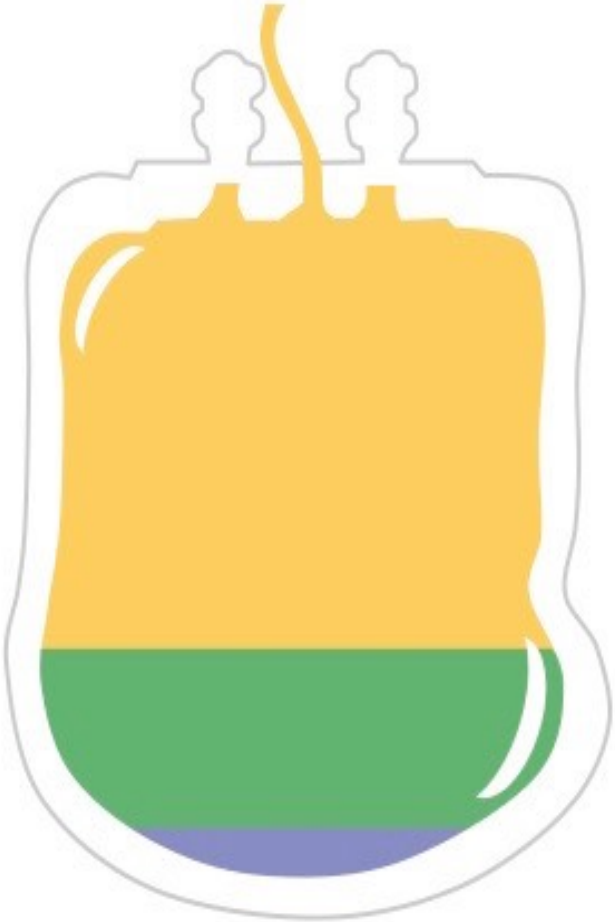
- 90% water.

- 6-8% plasma proteins.

- 1% electrolytes.

- 1-3% other solutes including:
  - Nutrients (e.g. glucose, amino acids, vitamins)
  - Hormones
  - Wastes
  - Blood gases

Plasma Proteins



Major Types:

Albumin *(60%)*

Major component of osmotic pressure of plasma

Globulins *(35%)*

Antibodies (immunoglobulin) and transport proteins

Fibrinogens *(4%)*

Functions in blood clotting

Other *(<1%)*

Various roles (α-1-antitrypsin, coagulation factors, etc.)

Functions of Plasma Proteins:

1- Generation of plasma colloid osmotic pressure (oncotic pressure):

most capillary walls are relatively impermeable to the proteins in plasma, therefore they exert an osmotic force of about 25 mm Hg across the capillary wall (oncotic pressure that pulls water into the blood). *Albumin* is the most abundant protein in plasma.

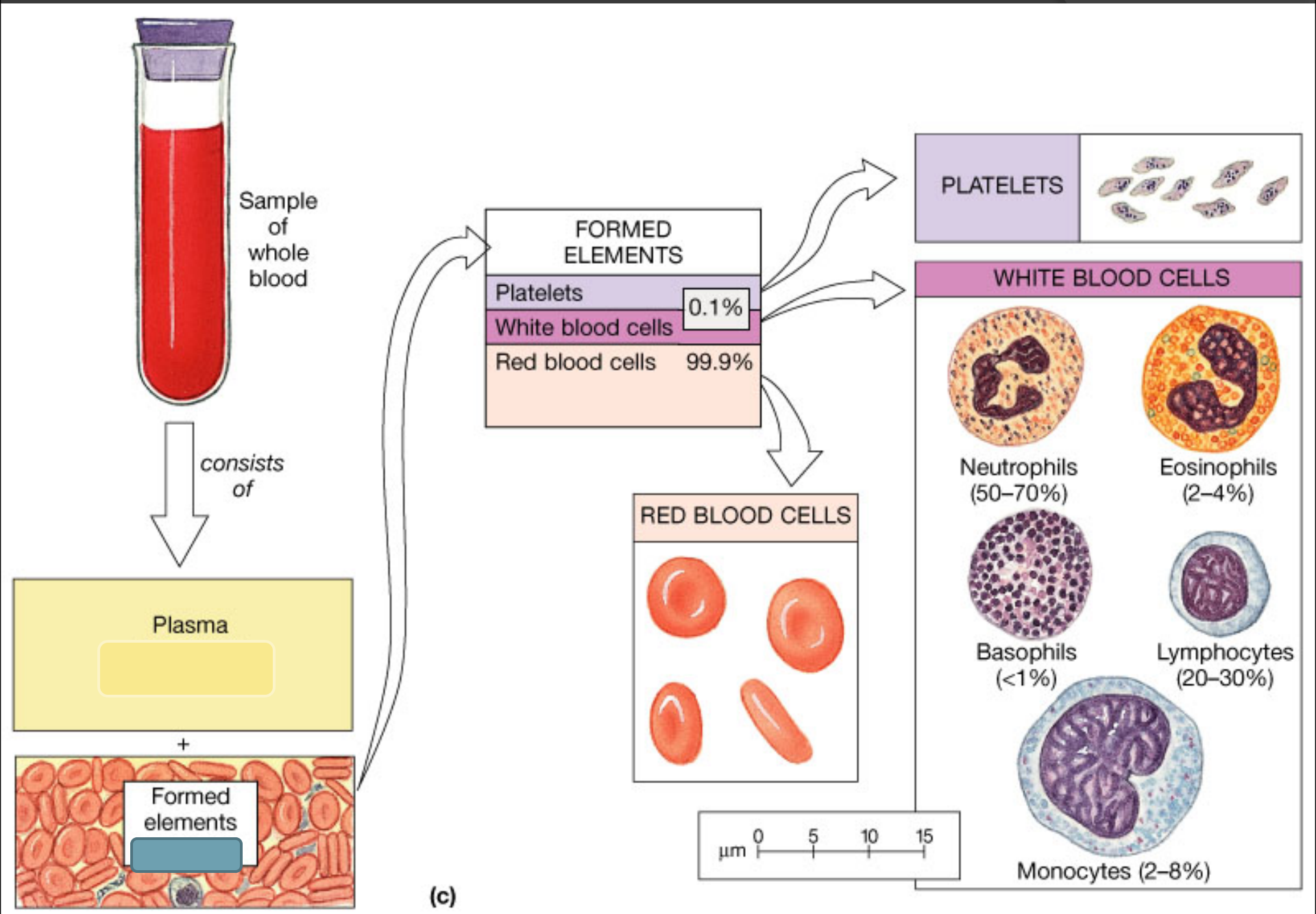
2- Buffering function of plasma proteins:

plasma proteins are responsible for 15% of the buffering capacity of the blood. *All types of plasma proteins*.

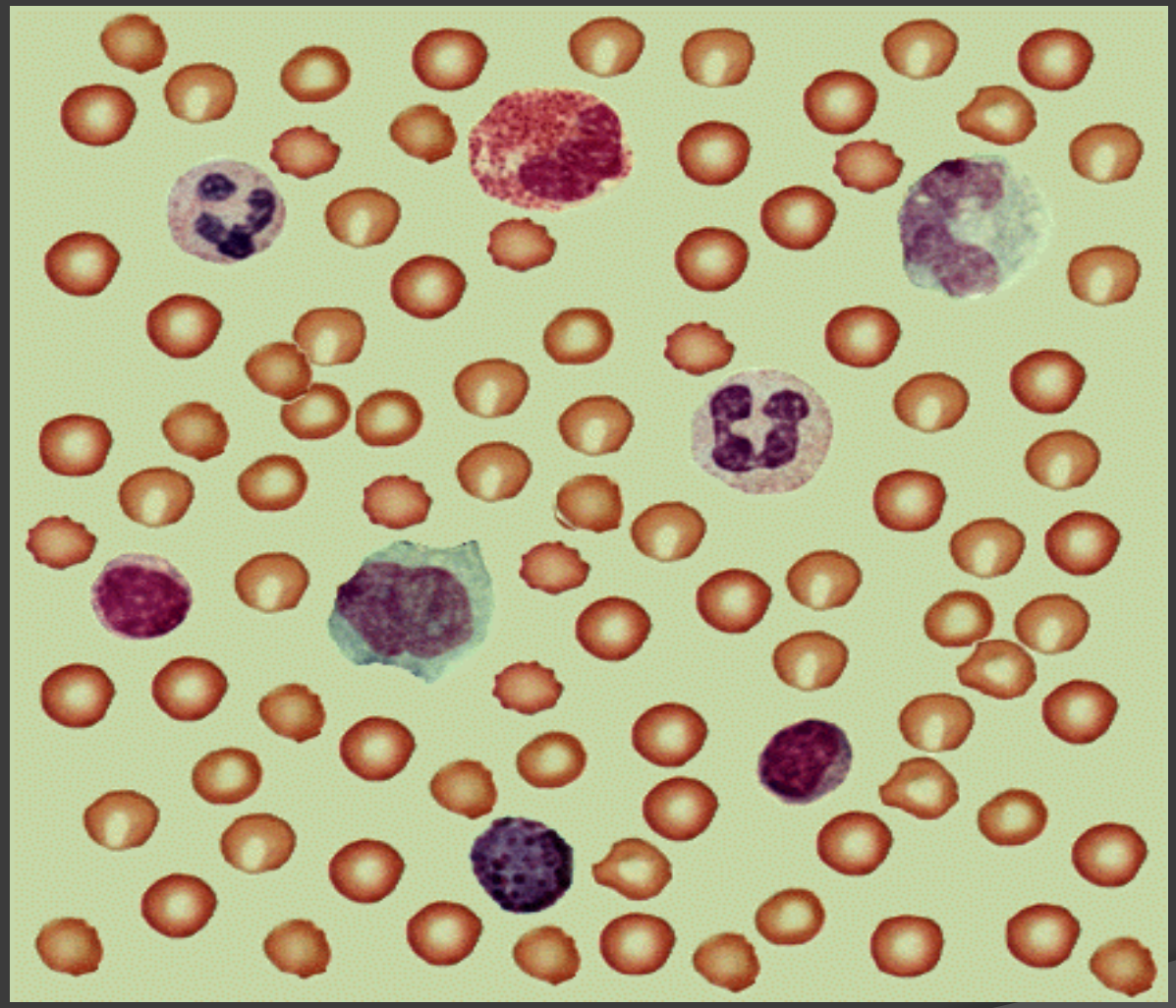
3- N**onspecific carriers for various hormones** (e.g., cortisol, thyroxin), **other solutes** (e.g. iron, cupper), and drugs. *Albumin + α Globulins*

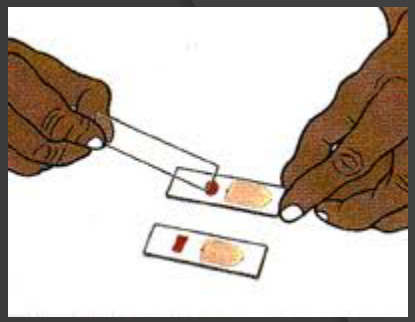
4- Defence: *Gamma globulins* are antibodies *Y Globulins*

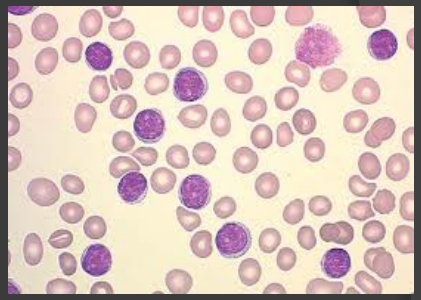
5- Blood clotting: *Fibrinogen, prothrombin, β Globulins.*



Blood Film

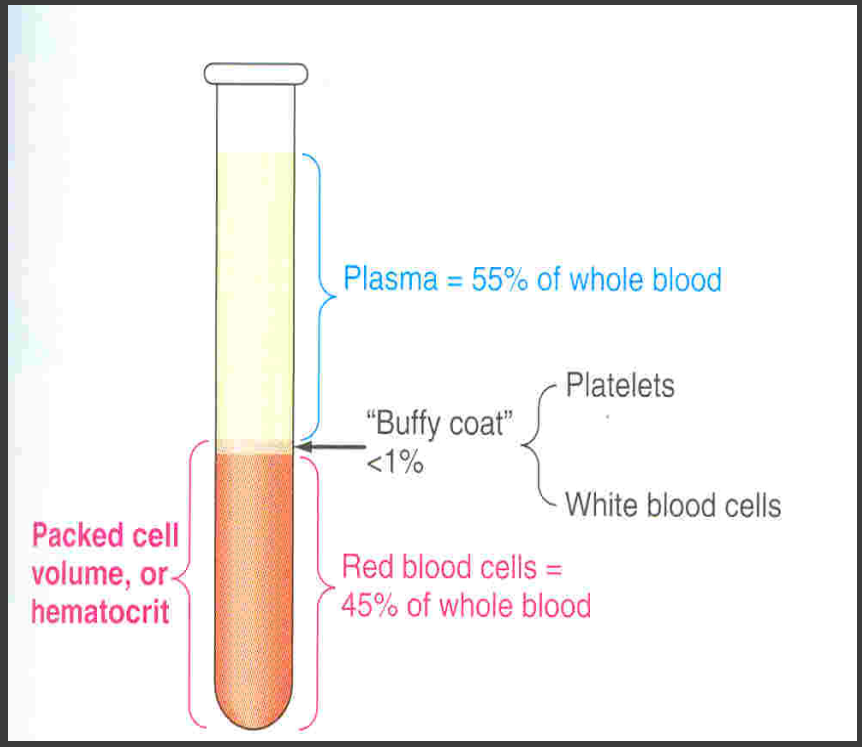






Blood Volume

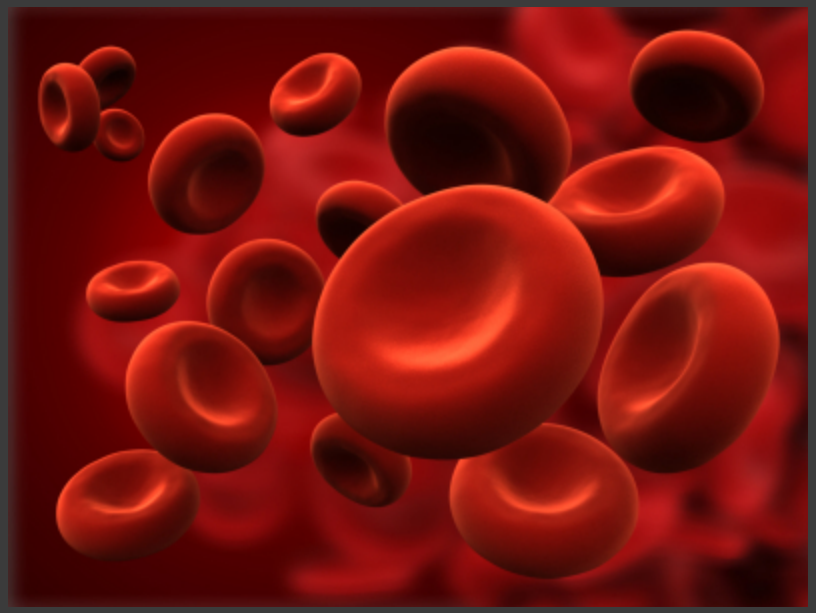
- **5 liter** in adult:
  - **45%** is packed cells volume (PCV).
  - **55%** is plasma volume.



Blood Cells Formation

- Erythropoiesis: Formation of RBC (erythrocytes)
- Leucopoiesis: Formation of WBC (leucocytes)
- Thrombopoiesis: Formation of platelets (thrombocytes)

Red Blood Cells (RBC):



- **Function:**
  - O_2 transport
  - CO_2 transport
  - Buffer

Red Blood Cells

Shape & size

- Flat Biconcave Disc.
- Non-nucleated.
- Diameter 7-8
- Flexible
- Average volume 90-95 μm^3
- Number = 4.7 - 5 $x10^6$
- Hb = 14-16 g/dl

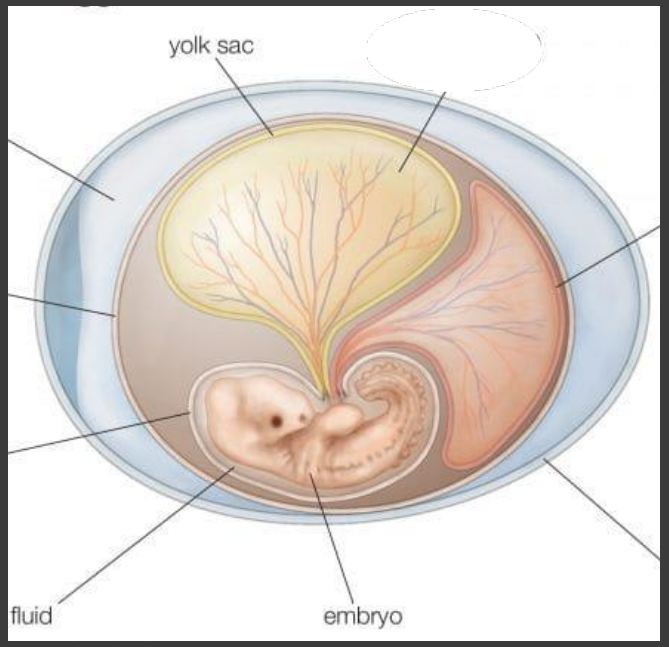
Production of RBC

In-utero:

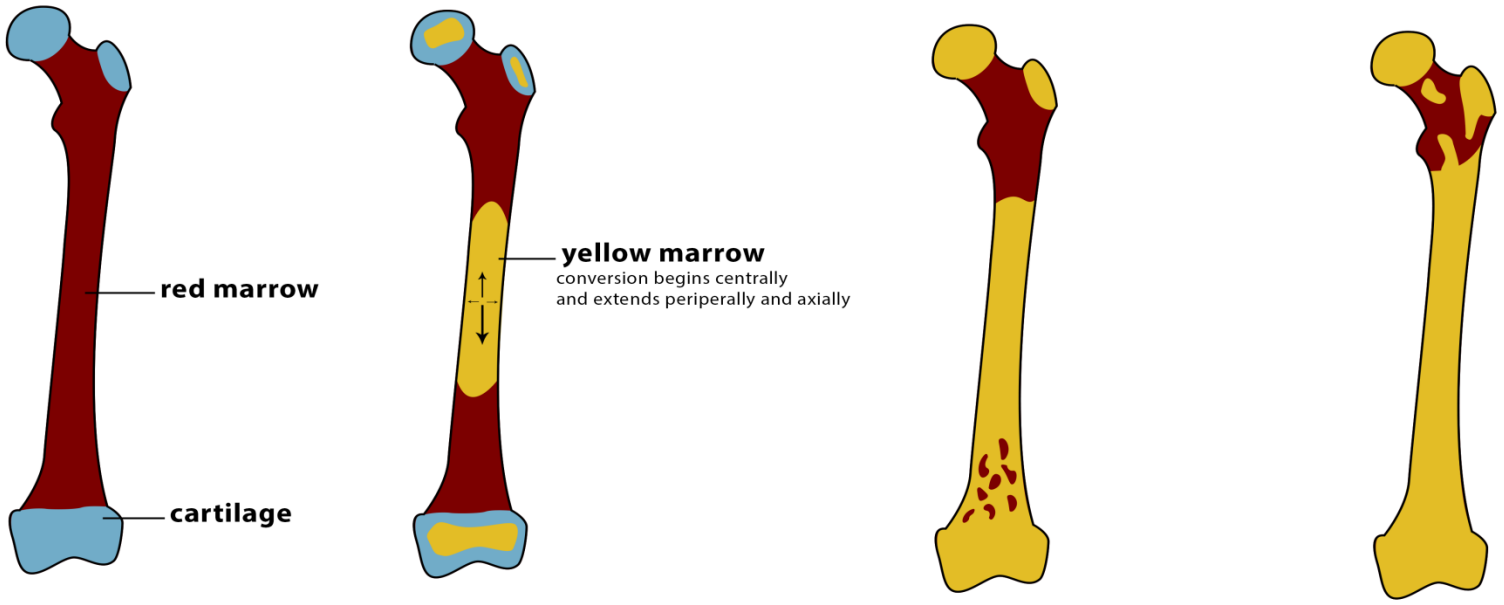
- Early few weeks of embryo nucleated RBCs are formed in *yolk sac.*
- Middle trimester mainly in *liver & spleen & lymph nodes.*
- Last months RBCs are formed in *bone marrow* of all bones

After Birth:

- *Bone marrow* of flat bone continue to produce RBC into adult life.
- Shaft of long bone stop to produce RBC at puberty while epiphysis continue.


yolk sac
fluid
embryo

Normal bone marrow conversion



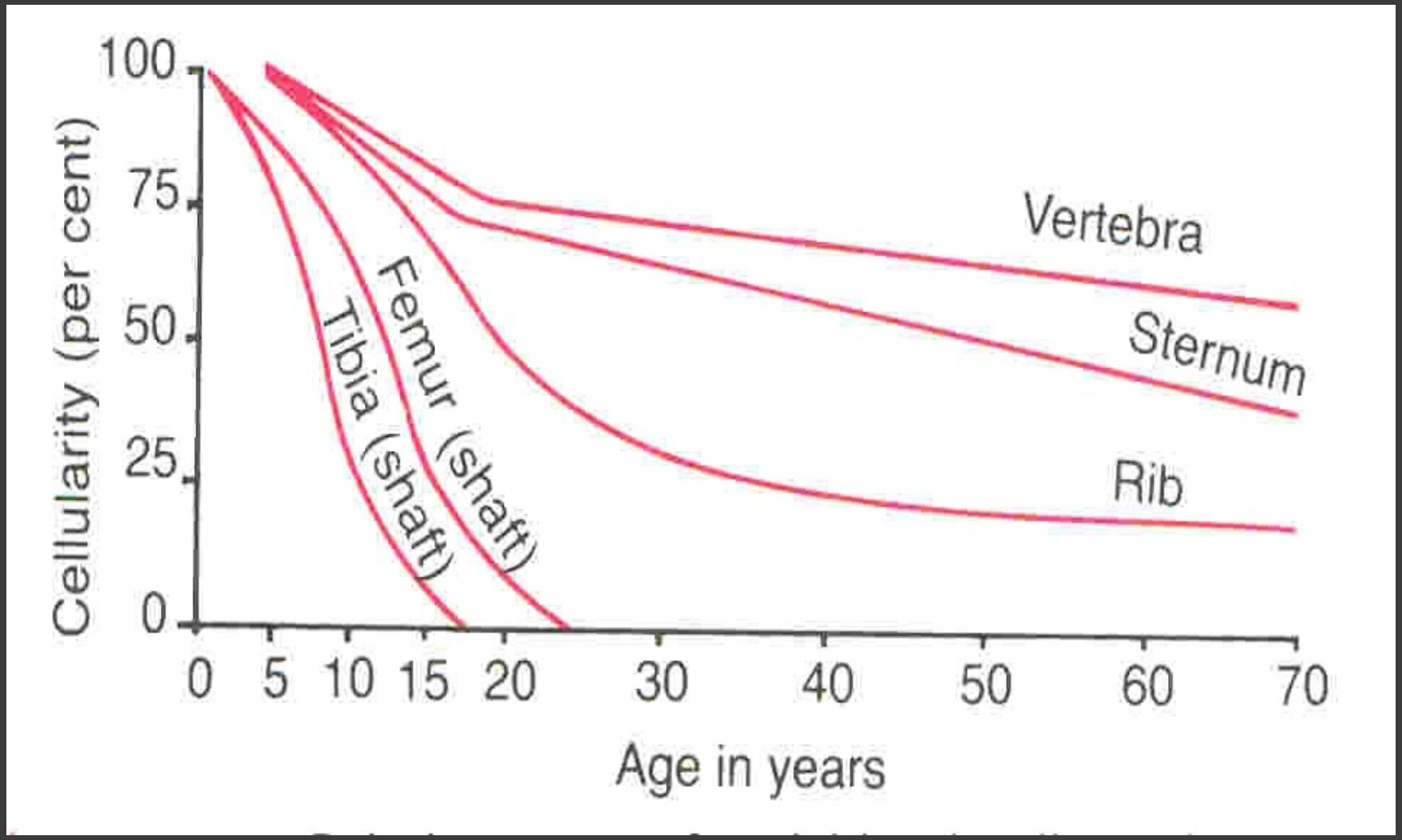
Infant
<1 year

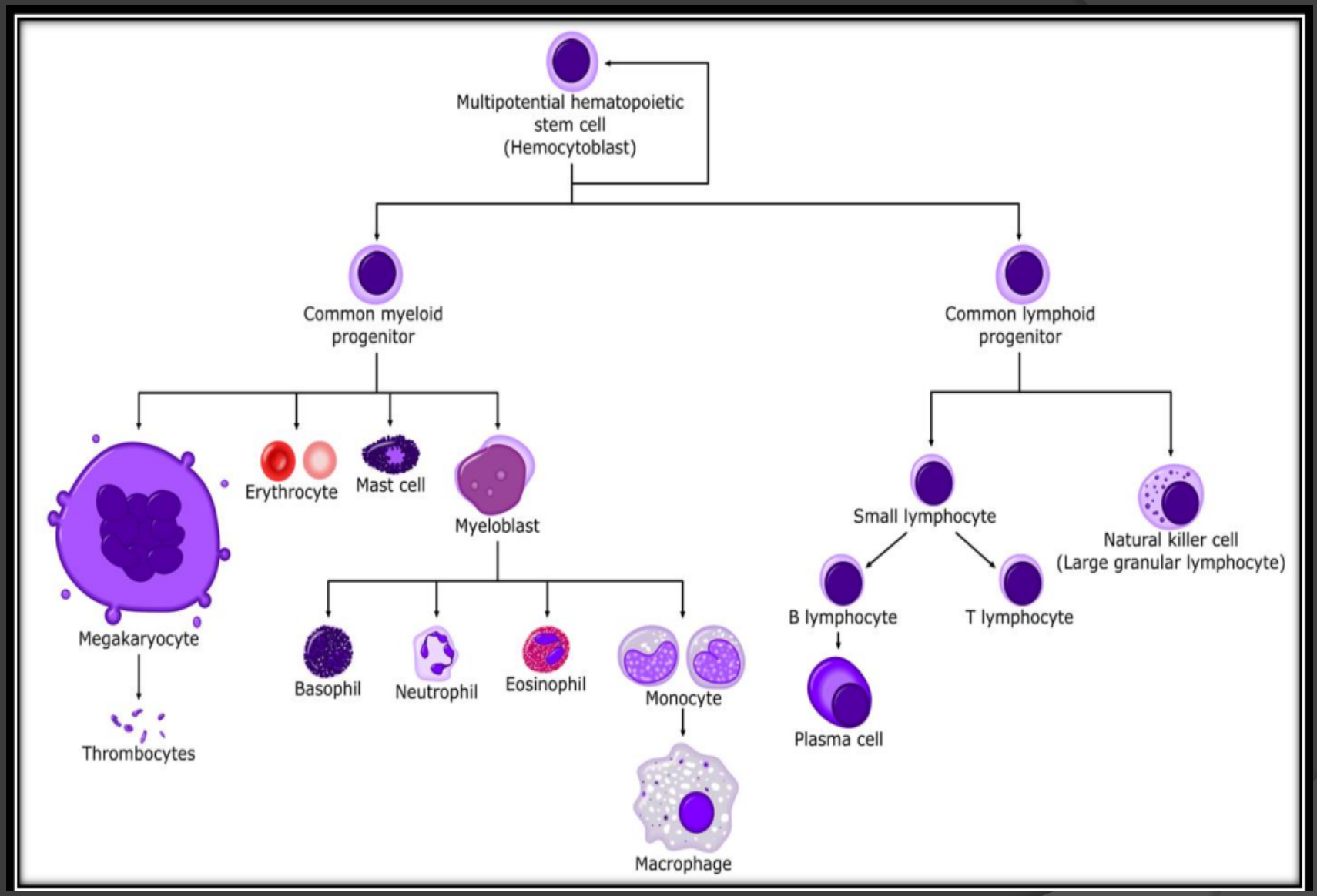
Childhood
1-10 years

Adolescent
10-20 years

Adult
>25 years

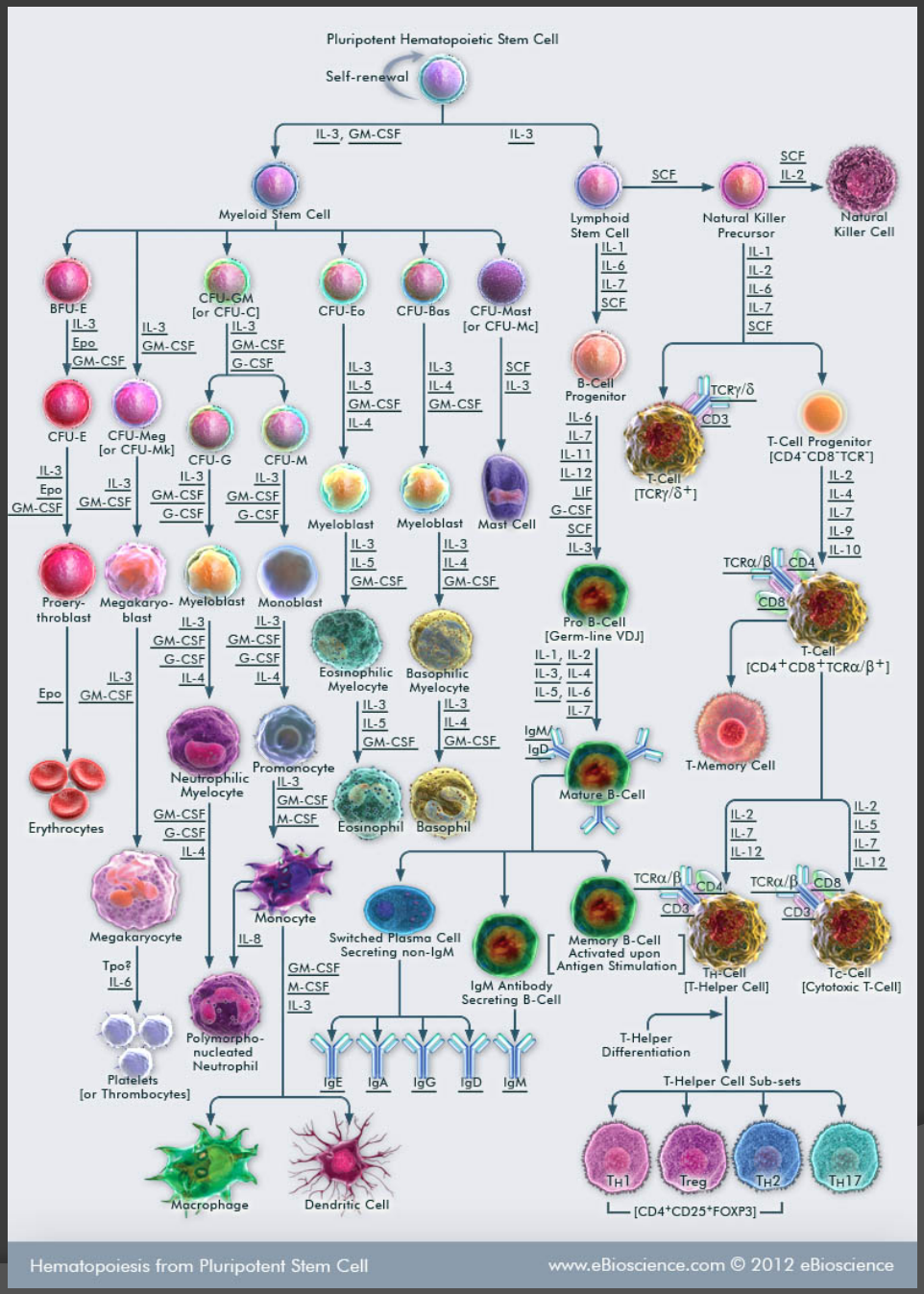
Production of RBC





Pluripotent Stem Cells in Bone Marrow & Cord Blood

By Ambreen Shaikh and Deepa Bhartiya


Pluripotent Hematopoietic Stem Cell
Self-renewal
IL-3, GM-CSF
IL-3
Myeloid Stem Cell
Lymphoid Stem Cell
SCF
Natural Killer Precursor
SCF
IL-2
Natural Killer Cell
BFU-E
CFU-GM [or CFU-C]
CFU-Eo
CFU-Bas
CFU-Mast [or CFU-Mc]
IL-3
Epo
GM-CSF
IL-3
GM-CSF
IL-3
GM-CSF
G-CSF
IL-3
IL-5
GM-CSF
IL-4
IL-3
IL-4
GM-CSF
SCF
IL-3
IL-1
IL-6
IL-7
SCF
IL-1
IL-2
IL-6
IL-7
SCF
B-Cell Progenitor
TCRγ/δ
CD3
T-Cell [TCRγ/δ+]
T-Cell Progenitor [CD4-CD8-TCR-]
IL-6
IL-7
IL-11
IL-12
LIF
G-CSF
SCF
IL-3
IL-2
IL-4
IL-7
IL-9
IL-10
CFU-E
CFU-Meg [or CFU-Mk]
CFU-G
CFU-M
Myeloblast
Myeloblast
Mast Cell
IL-3
Epo
GM-CSF
IL-3
GM-CSF
IL-3
GM-CSF
G-CSF
IL-3
GM-CSF
G-CSF
IL-3
IL-5
GM-CSF
IL-3
IL-4
GM-CSF
Proery-throblast
Megakaryo-blast
Myeloblast
Monoblast
Pro B-Cell [Germ-line VDJ]
TCRα/β
CD4
CD8
T-Cell [CD4+CD8+TCRα/β+]
IL-1, IL-2
IL-3, IL-4
IL-5, IL-6
IL-7
Epo
IL-3
GM-CSF
IL-3
GM-CSF
G-CSF
IL-4
IL-3
GM-CSF
G-CSF
IL-4
Eosinophilic Myelocyte
Basophilic Myelocyte
IgM/IgD
T-Memory Cell
Neutrophilic Myelocyte
Promonocyte
IL-3
GM-CSF
M-CSF
IL-3
IL-5
GM-CSF
IL-3
IL-4
GM-CSF
Mature B-Cell
Erythrocytes
Eosinophil
Basophil
IL-2
IL-7
IL-12
IL-2
IL-5
IL-7
IL-12
GM-CSF
G-CSF
IL-4
Megakaryocyte
Monocyte
Switched Plasma Cell Secreting non-IgM
IgM Antibody Secreting B-Cell
Memory B-Cell Activated upon Antigen Stimulation
TCRα/β
CD4
CD3
TH-Cell [T-Helper Cell]
TCRα/β
CD8
CD3
TC-Cell [Cytotoxic T-Cell]
Tpo?
IL-6
IL-8
GM-CSF
M-CSF
IL-3
Platelets [or Thrombocytes]
Polymorpho-nucleated Neutrophil
IgE
IgA
IgG
IgD
IgM
T-Helper Differentiation
T-Helper Cell Sub-sets
Macrophage
Dendritic Cell
TH1
Treg
TH2
TH17
[CD4+CD25+FOXP3]
Hematopoiesis from Pluripotent Stem Cell
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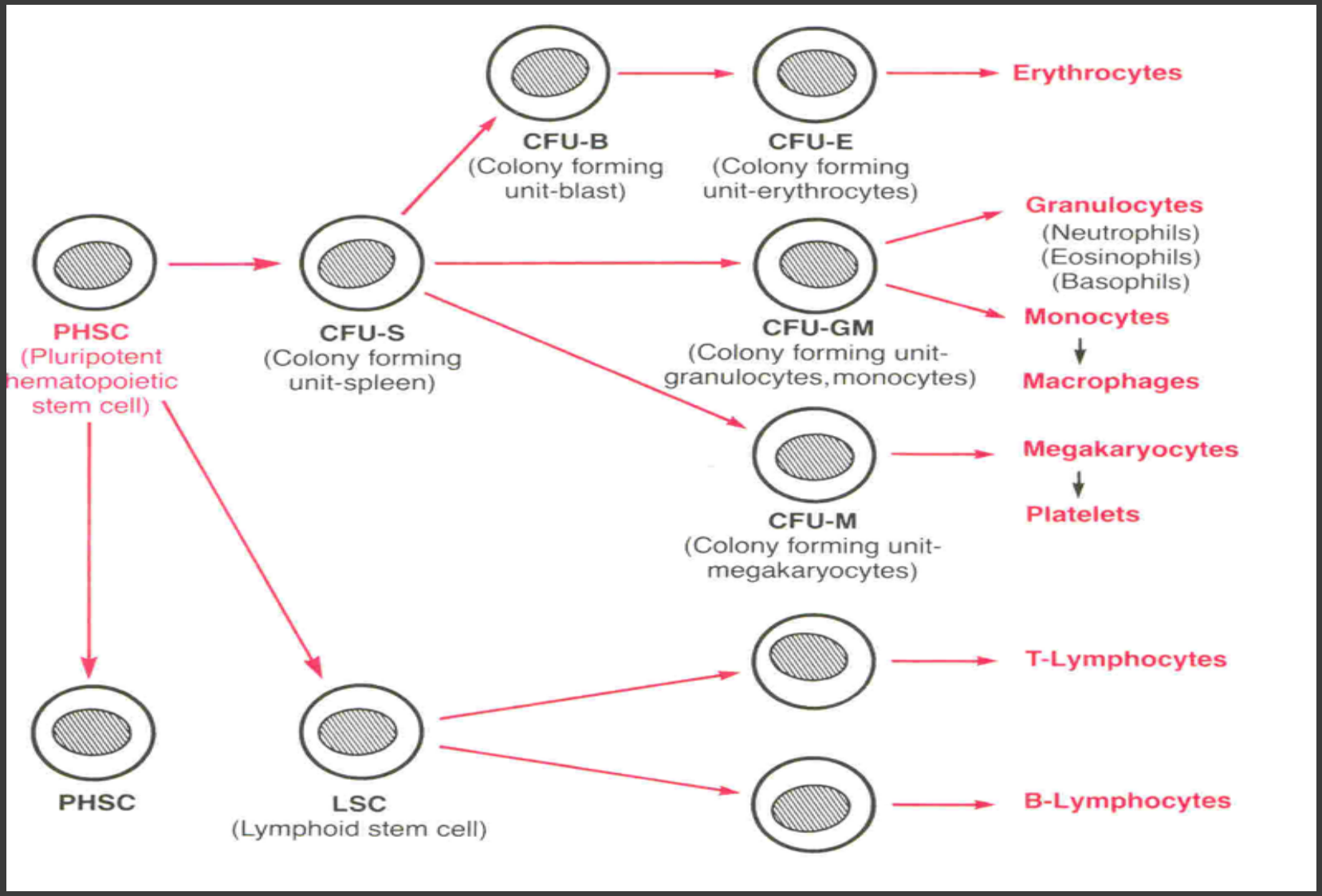
Genesis (Production) of RBC

All blood cell are formed from **Pluripotential hematopoietic stem cells** ⇒ committed cells:

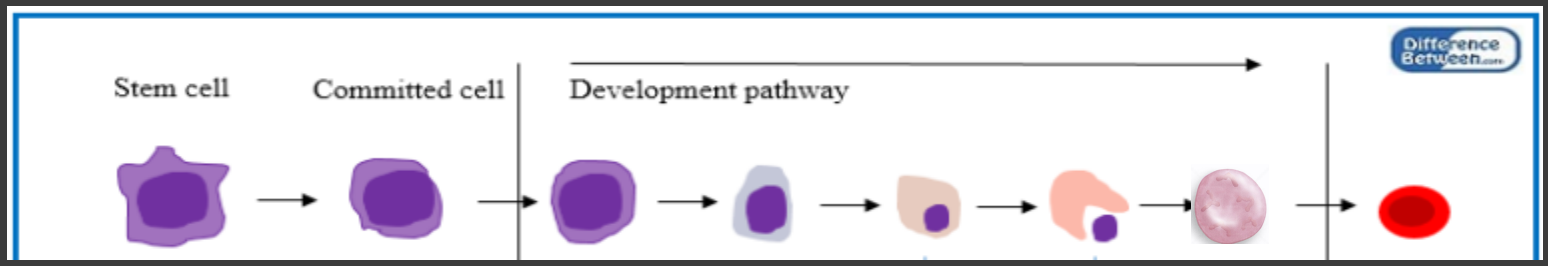
- Committed stem cells for **RBC.**
- Committed stem cells for WBC.

- Growth of different stems cells are controlled by different *growth factors.*

Genesis (production) of RBC



Stages of RBC development & differentiation:



- Committed stem cell
  - Proerthroblast.
  - basophil erythroblast
  - polychromatophil erythroblast
  - orthochromatic erythroblast
  - Reticulocytes
  - Mature erythrocytes

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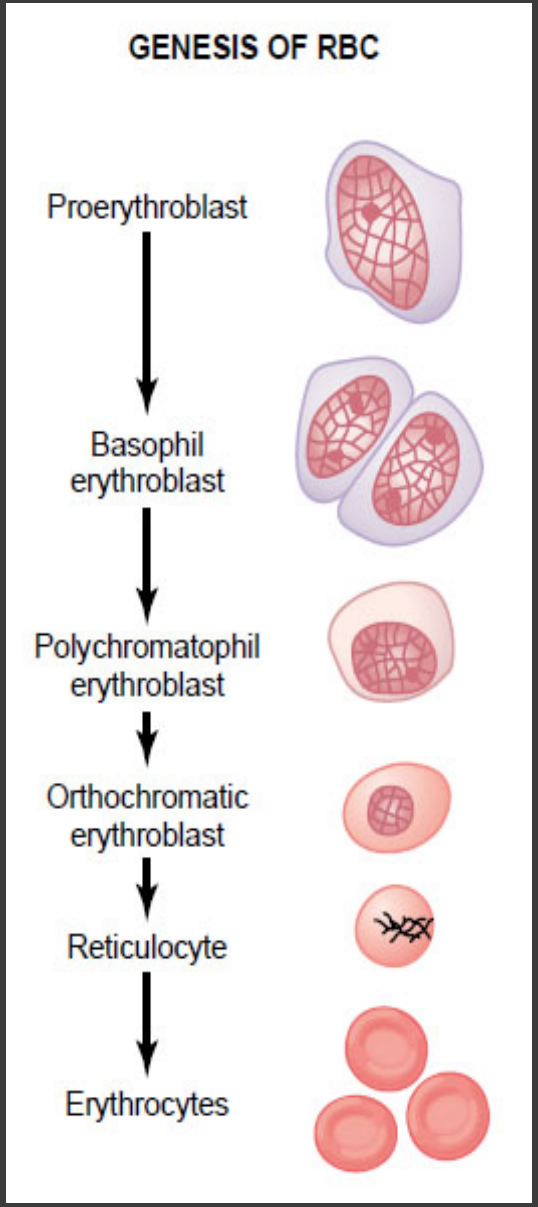
*In cases of rapid RBC production → ↑ reticulocytes in the circulation.

Erythropoiesis

- **RBC development is characterize by:**
  - decrease in cell size.
  - disappearance of nucleus.
  - appearance of hemoglobin (Hb)

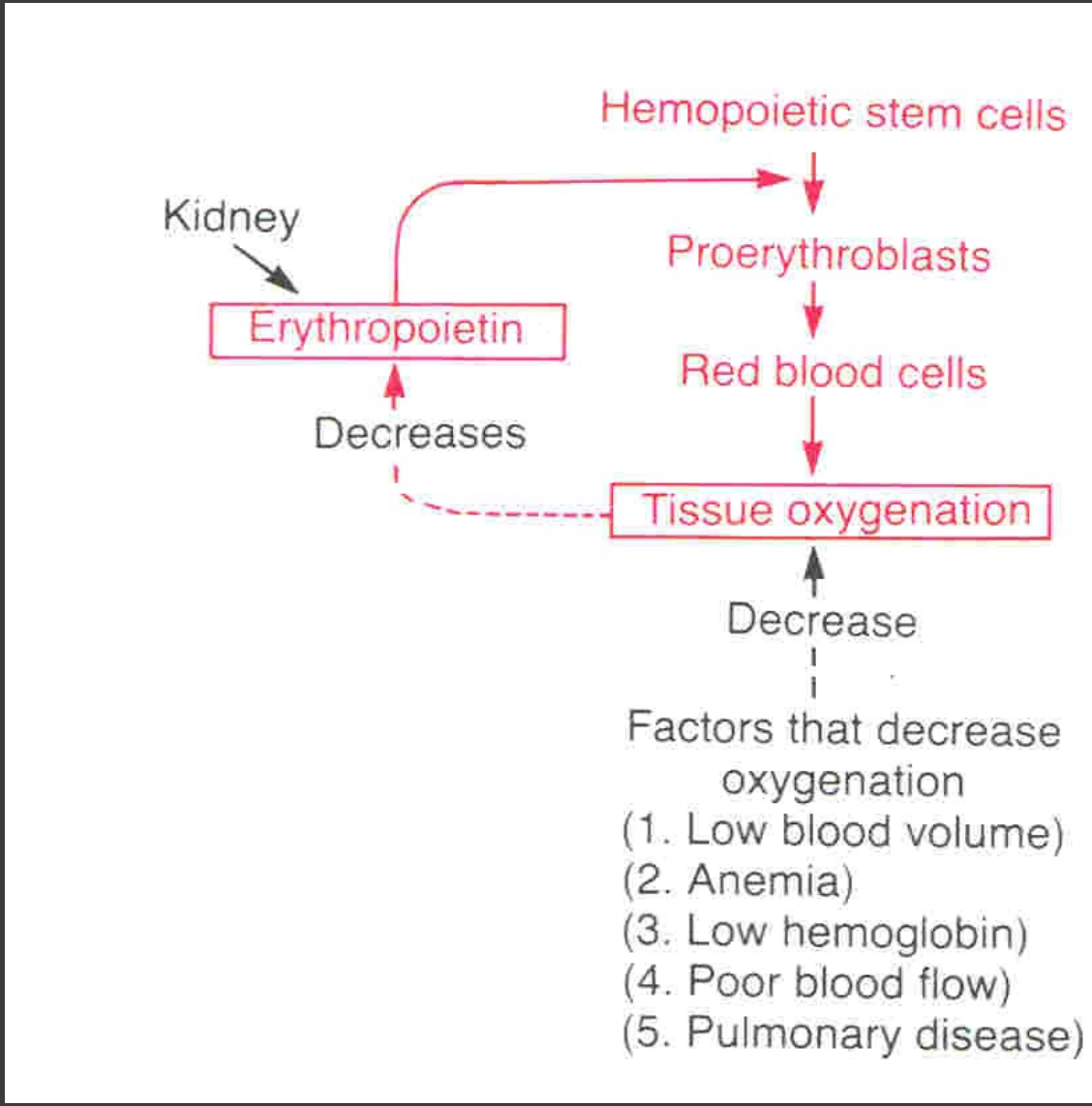


Regulation of RBC production:

- Erythropoiesis is stimulated by erythropoietin hormone produced by the kidney in response to hypoxia (low oxygen in the blood)

- Hypoxia (↓ oxygen) caused by:
  - Low RBC count (Anaemia)
  - Hemorrhage
  - High altitude
  - Prolong heart failure
  - Lung disease

Tissue oxygenation and RBC formation



Erythropoietin:

- Glycoprotein.
- 90% from renal cortex 10% liver.
- Stimulate the growth of early stem cells.
- Does not affect maturation process.
- Can be measured in plasma & urine.
- conditions like:

  - High altitude
  - Heart failure
  - Lung Disease

  Result in High erythropoietin levels and polycythemia

Role of the kidneys in RBC formation