8 Blood physiology

ملاحظة : تم دمج محاضرتي كريات الدم الحمراء لارتباطها الوثيق ببعضها الآخر

- Very important
- Extra information
- Terms

(ذلكَ عَالمُ الغيب وَالشهادةِ العزيزُ الرحِيم * الذِي أَحسنَ كل شيءٍ خَلَقَهُ وَبَدأَ خَلق الإنسان من طِينٍ * ثم جَعَل نسلهُ من سلالةٍ مِن مَاءٍ مَهِينٍ * ثُمَ سواهُ وَنَفَخ فِيه مِنْ رُوحِه وَجَعلَ لَكم السّمعَ وَالْأَبصَارَ وَالْأَفئدَةَ قليلًا مَا تَشكرون) [السجدة: ٦ - ٩].

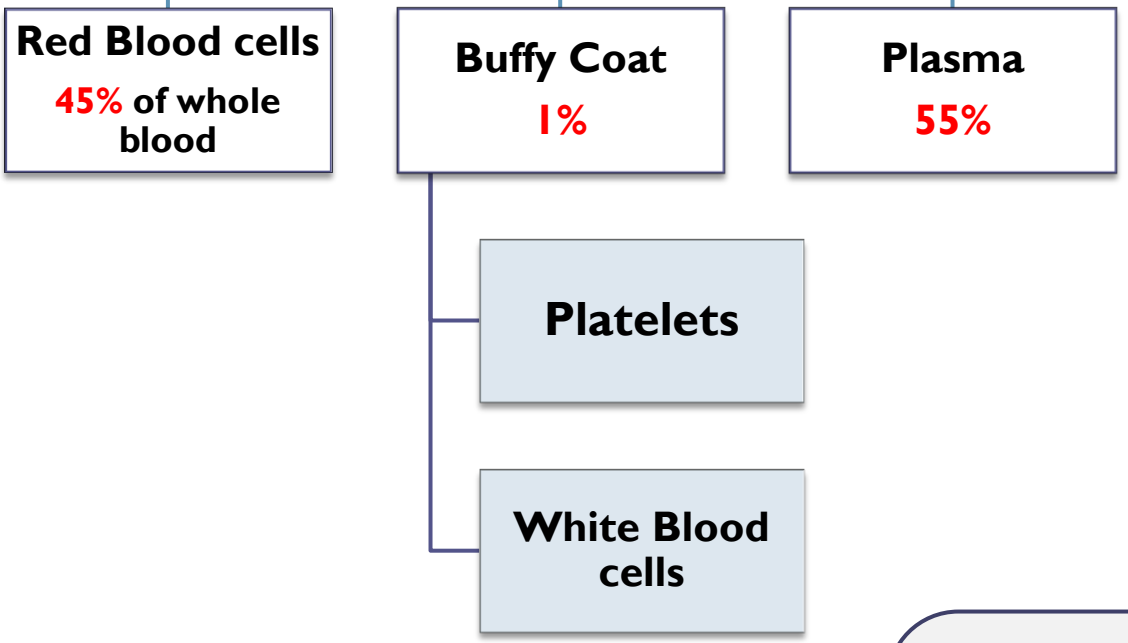
Contact us : Physiology435@gmail.com

Objectives:

- At the end of this lecture you should be able to:
- Describe Cellular and non-cellular components of blood.
- Recognize functions of blood.
- Define Erythropoiesis; leucopoiesis, thrombopoiesis.
- Recognize sites of RBC formation at different developmental age.
- Describe different stages of RBC differenation.
- Describe features of RBC maturation.
- Describe regulation of RBC production and erythropoietin hormone secretion in response to hypoxia.
- Recognize clinical conditions associated with high level of erythropoitein in the blood.

Contact us : Physiology435@gmail.com

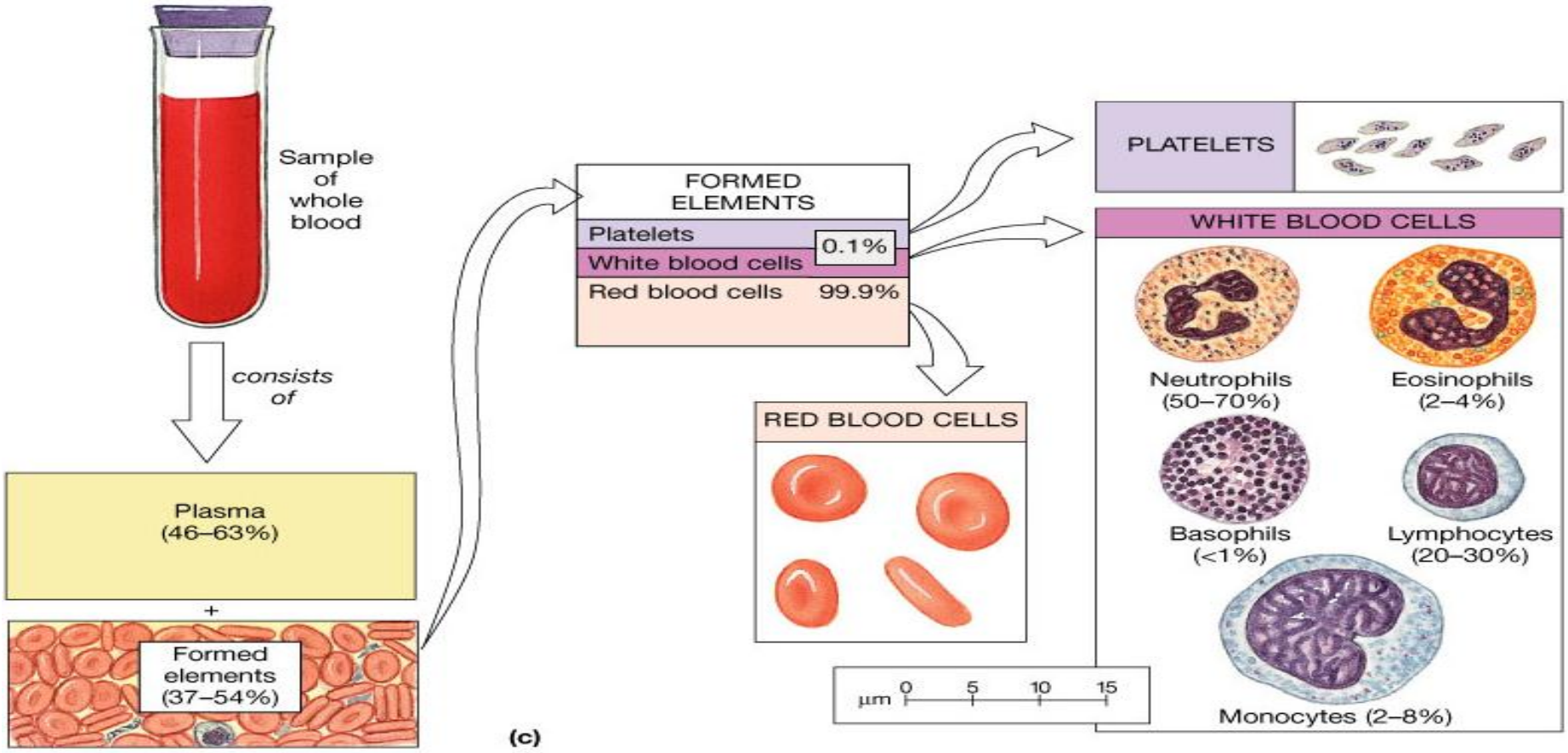
Blood composition



The hematocrit is the proportion, by volume, of the blood that consists of red blood cells.
The hematocrit (HCT) is expressed as a percentage of the volume of whole blood that is made up of red blood cells. This measurement depends on the number of red blood cells.
Hematocrit is also called packed-cell volume (PCV).
For better understanding see :
Video1 & Video2 & Video3

Note: the hematocrit differs from males to females. Males have more blood cells because females lose every month half a letter from blood.
* Hematocrit is from 38% to 46% in females, 42% to 54% in males.
* Buffy coat is a hazy layer

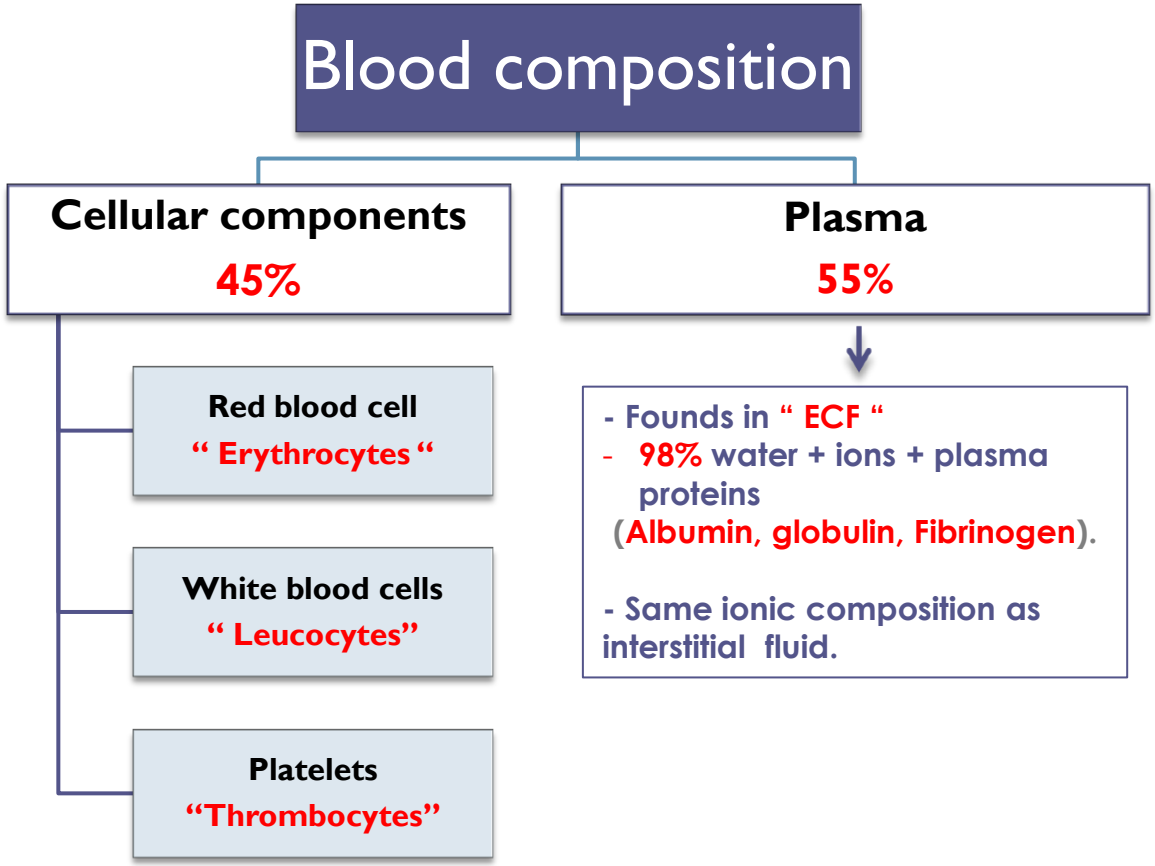
Contact us : Physiology435@gmail.com



- **Note:** : red blood cells are in millions while white blood cells are in thousands
- red blood cells and platelets do not have nucleus. White blood cells have nucleus.
- The reason that the RBC don't have nucleus is to do its function efficiently

Contact us : Physiology435@gmail.com

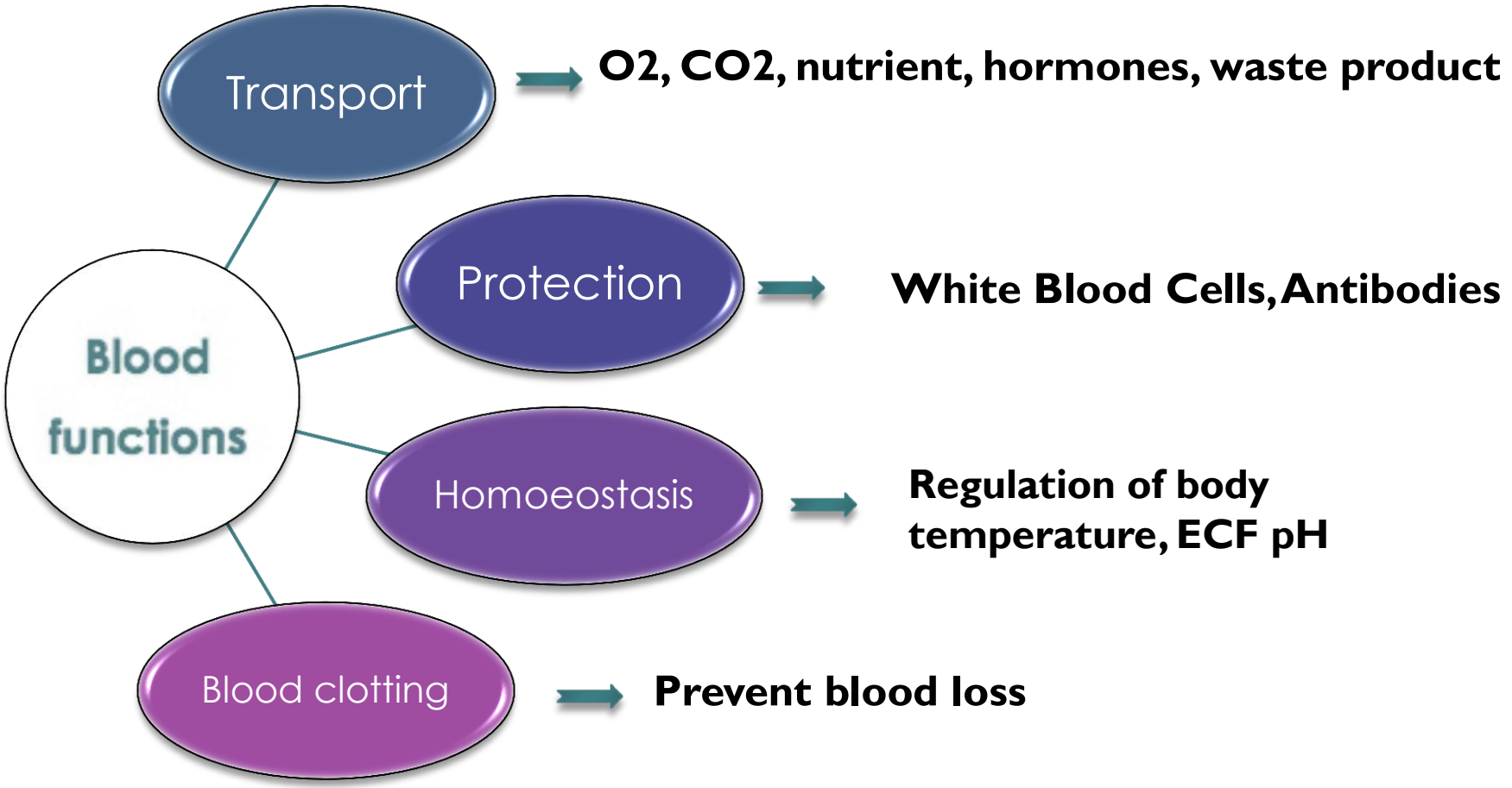
Blood composition



Note: erytho = red , leuco = white
- plasma has more protein than the interstitial fluid

Contact us : Physiology435@gmail.com

Function of blood



Contact us : Physiology435@gmail.com

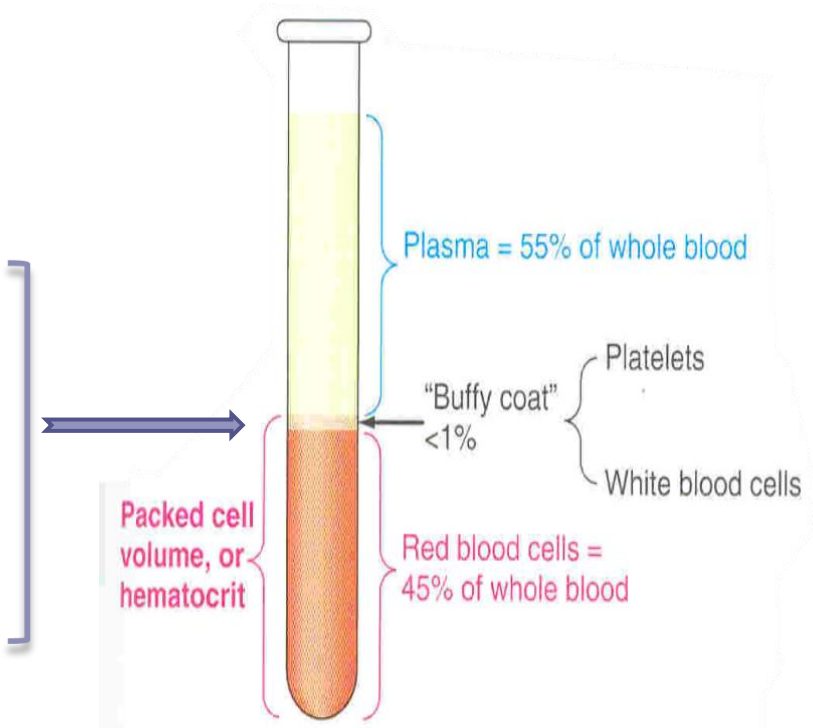
Blood Volume

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

Blood percentage higher in male more than female

" to compare between two person they should have the same size + age "

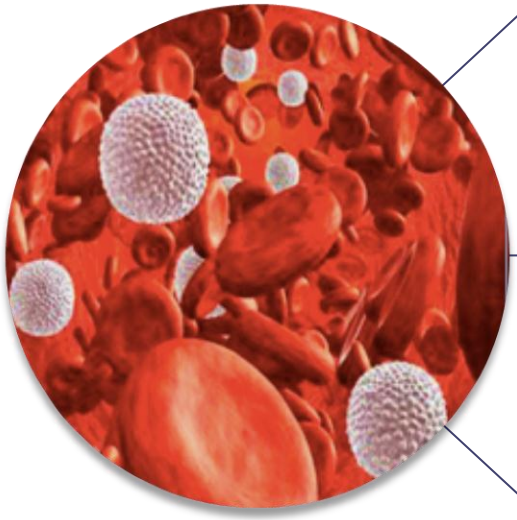
When you leave a blood sample for a period of time, the RBC will be separated from the plasma ؛so the RBC becomes in the bottom of the tube " in red color " **and the plasma at the top of the tube** " in yellow color "



Contact us : Physiology435@gmail.com

Extra information

Blood cells formation



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

Contact us : Physiology435@gmail.com

Poiesis = تصنيع

Red blood cells (RBC)

Function

- Buffer
- CO_2 transport
- O_2 transport

Shape and size

- Flat Biconcave Disc.
- Non-nucleated.
- Diameter 7-8 µmx2.5µmx1 µm.
- Flexible.
- Average volume 90-95 μm^3
- Number = 4.7 - 5 $x10^6$
- Hb = 14-16 g/dl in the blood

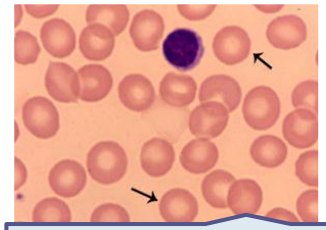
(Hb = Hemoglobin)

Contact us : Physiology435@gmail.com

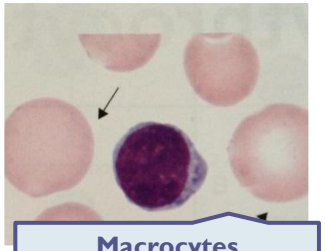
RBCs Size, Color, Indices

According to size :

Microcytes
(small sized RBCs)

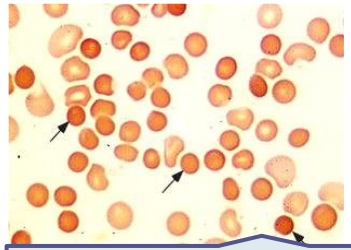


Normocytes
(Normal sized RBCs)

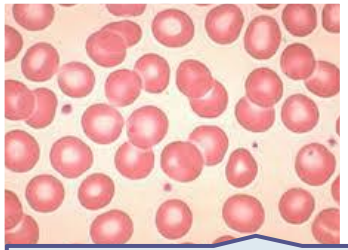


Macrocytes
(Large sized RBCs)

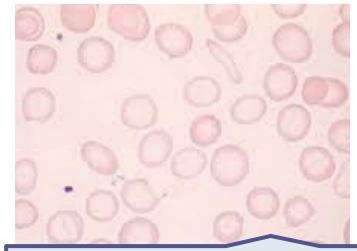
According to color :



Hyperchromia
(Darker due increased Hb)



Normochromia
(Normal colored RBCs)



Hypochromia
(paler due decreased Hb)

الصور خارجية وللإيضاح فقط/ Hb = hemoglobin / paler = شاحب

Contact us : Physiology435@gmail.com

RBCs Size, Color, Indices

They are determined by measuring the indices:

Mean corpuscular Volume :

"The average red blood cell size"

(MCV= 78 to 94 fl or 83 Cubic um)

Mean corpuscular hemoglobin :

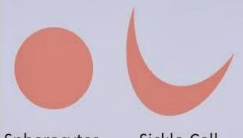
"The amount of hemoglobin per red blood cell"

(MCH= 27 – 32 picogram)

Mean corpuscular hemoglobin concentration :

"The amount of hemoglobin relative to the size of the cell or hemoglobin concentration per red blood cell"

(MCHC= 30 – 36 gm/dl)

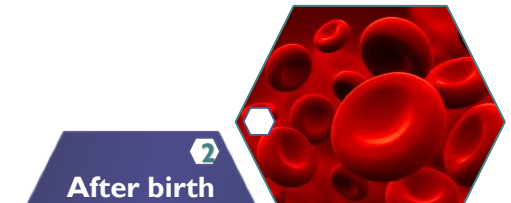
Microcytic Hypochromic Anemia	Macrocytic Normochromic Anemia	Microcytic hyperchromic Anemia
		 Spherocytes Sickle-Cell
MCHC: **<32 g/dL**	MCHC: **32 – 36 g/dL**	MCHC: **>36 g/dL**
Small sized RBCs with a large central pallor with concentration of hemoglobin decreased→ Hence **reduced MCHC**	Big sized RBCs with a normal central pallor but concentration of hemoglobin remains→ Hence **MCHC is normal**	Small sized RBCs with abnormal/without central pallor → increased hemoglobin concentration → hence **increased MCHC**

الجدول للإيضاح فقط

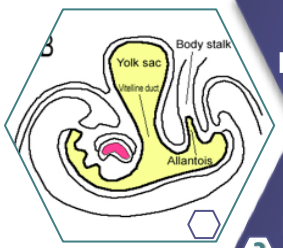
More explanation : Vedio

Contact us : Physiology435@gmail.com

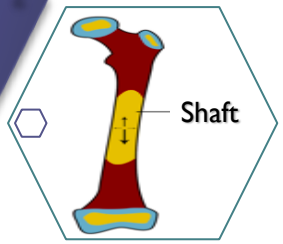
Production of RBC



After birth *Bone marrow* of flat bone continue to produce RBC



3 stages happened In-utero



Shaft of long bone stop to produce RBC at puberty while epiphysis continued

Early months 1-3

- **nucleated RBCs are formed in *yolk sac*** ***" the nucleus is needed for division then it's disappear"***

Middle months 3-6

- **RBCs are mainly formed in liver & spleen & lymph nodes**

Last months

- **RBCs are formed in bone marrow of all bones**

Contact us : Physiology435@gmail.com

Physiological Characteristics & Functions of RBC

- ①**Permeability**:

Semipermeable membrane, gas and urea freely passing through.

- ②**Plasticity**: **depends on:**

1) surface area-cubage ratio 2) viscosity of Hb. "لزوجة"

3) membrane elasticity and viscosity.

- ③**Osmotic fragility**:

Changes in RBC put into lower osmotic salty solution. Osmotic fragility of aged RBC is large and easily results in rupture (hemolysis and ghost cell).

Isosmotic solution : e.g. 0.85% NaCl & 1.4% NaHCO3 , 5% glucose.

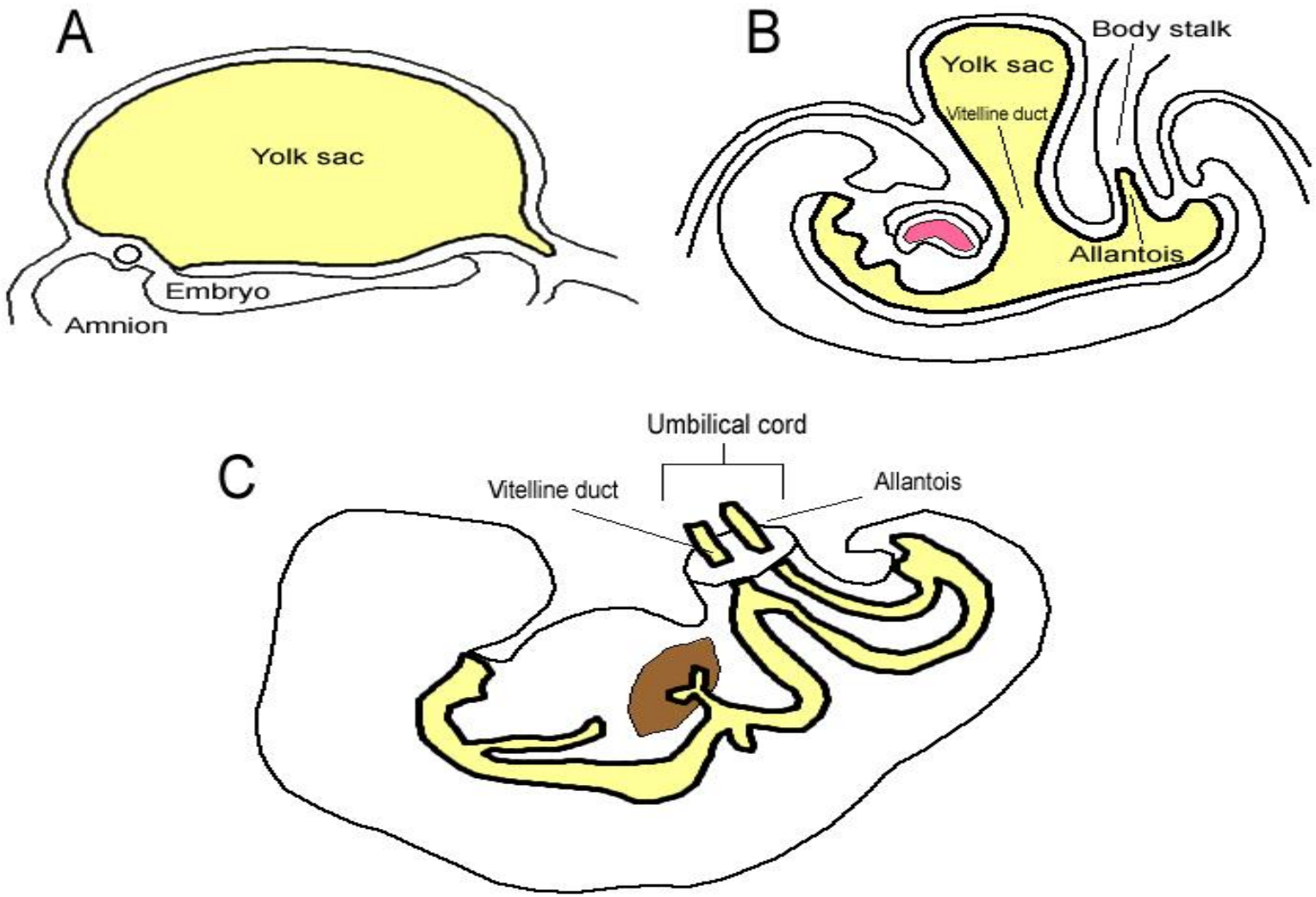
Isotonic solution : e.g. 0.85% NaCl.

- ④**Suspension stability:**

it can be described by erythrocyte sedimentation rate (ESR) معدل الترسيب

which is RBC descending distance per hour and suspension stability is inverse proportion to ESR.

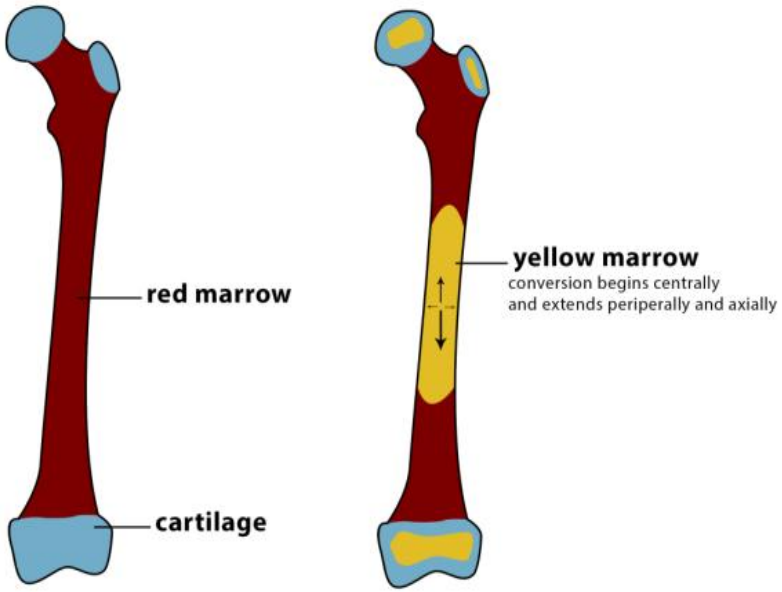
Normal value : male : 0~15 mm/h / female : 0~20 mm/h.



Production of RBC in utero

Contact us : Physiology435@gmail.com

Production of RBC after birth



Infant <1 year

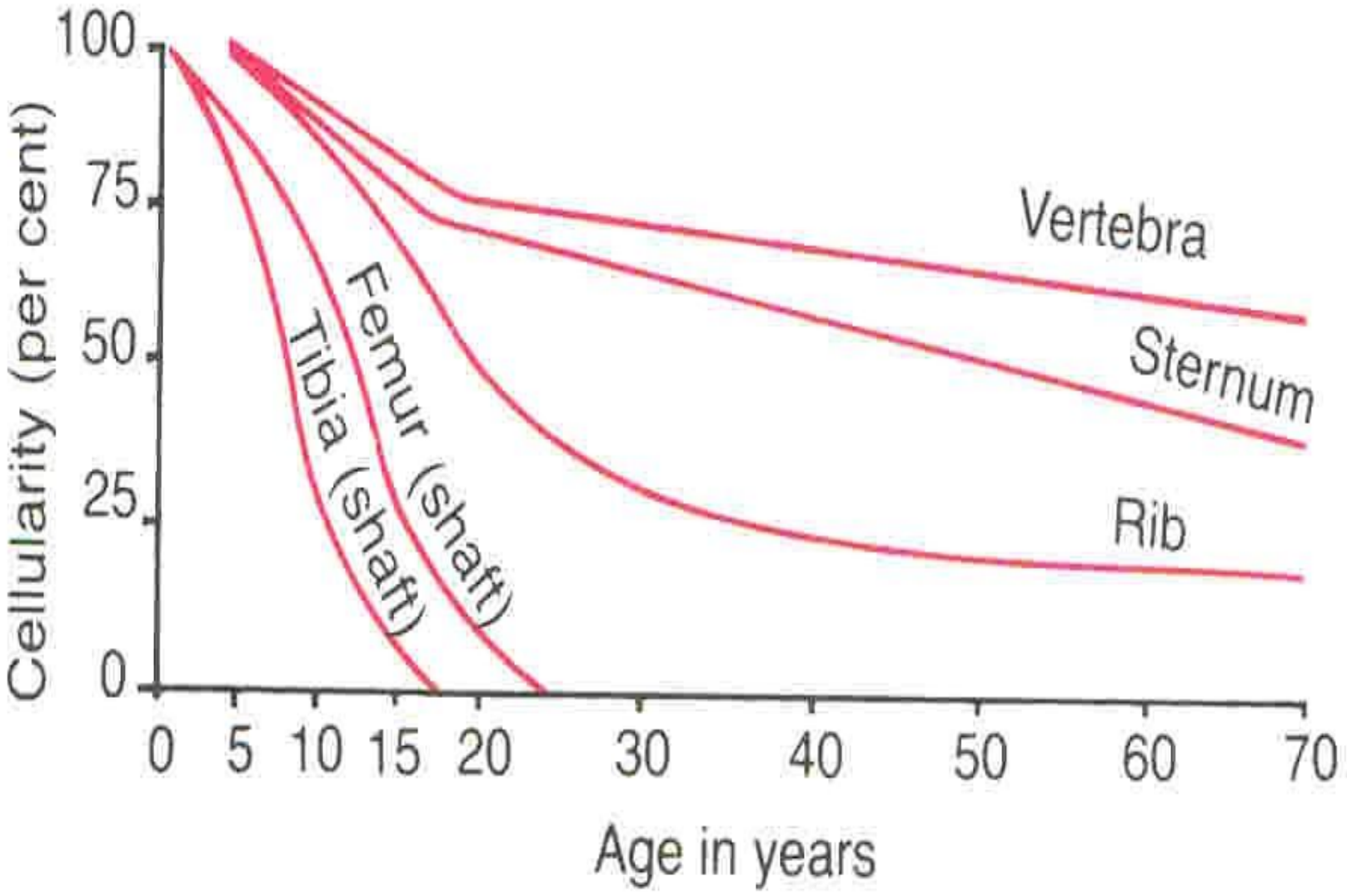
Childhood 1-10 years

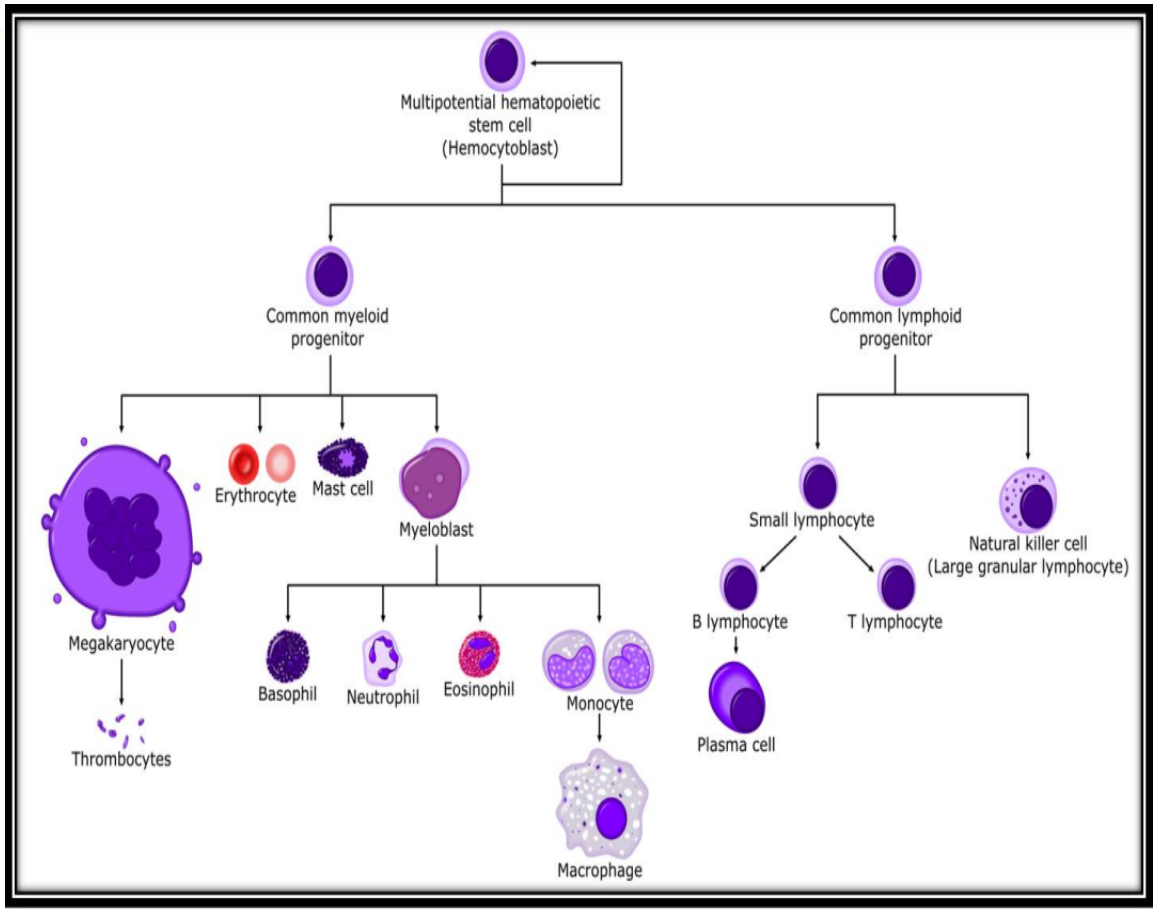
Adolescent 10-20 years

Adult >25 years

Note: Children need RBC more than adults for their growth

Production of RBCs in our life





شرح لمحتوى الصورة :

All blood cells are formed from (stem cells) > stem cell has two paths :

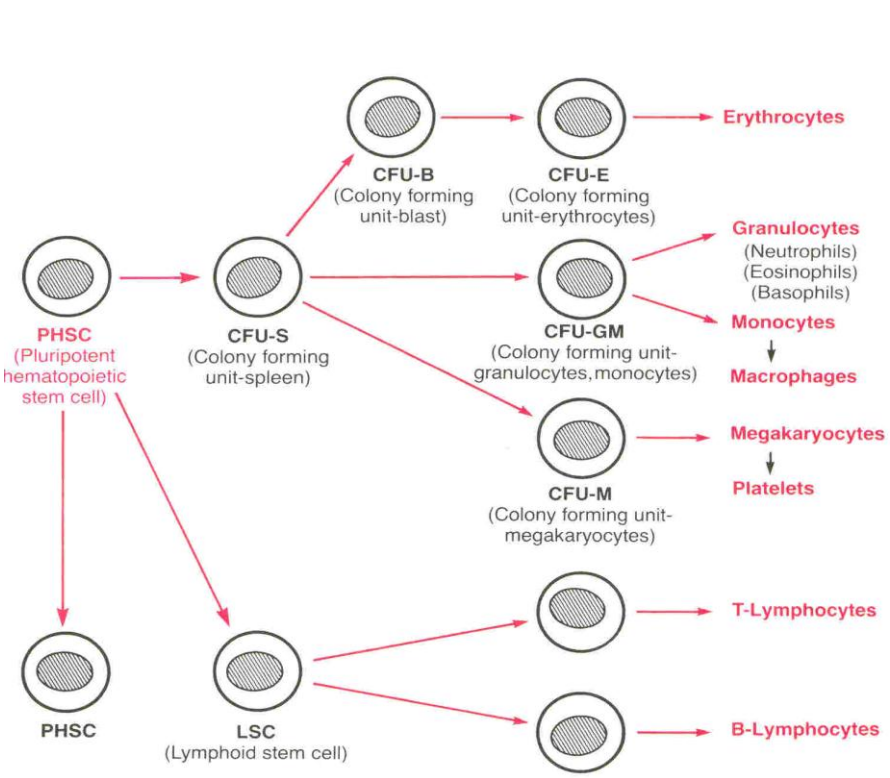
- One path is called " myeloid " ➡ that form (RBCs) + (some type of WBCs) + (Platelets) + (mast cell)

- The other path is called " lymphoid " ➡ that formed (lymphocyte) "another type of WBC"

Note: stem cells can differentiate into a lot of different cells.
- myeloblast gives white blood cells

Contact us : Physiology435@gmail.com

Genesis (Production) of RBC

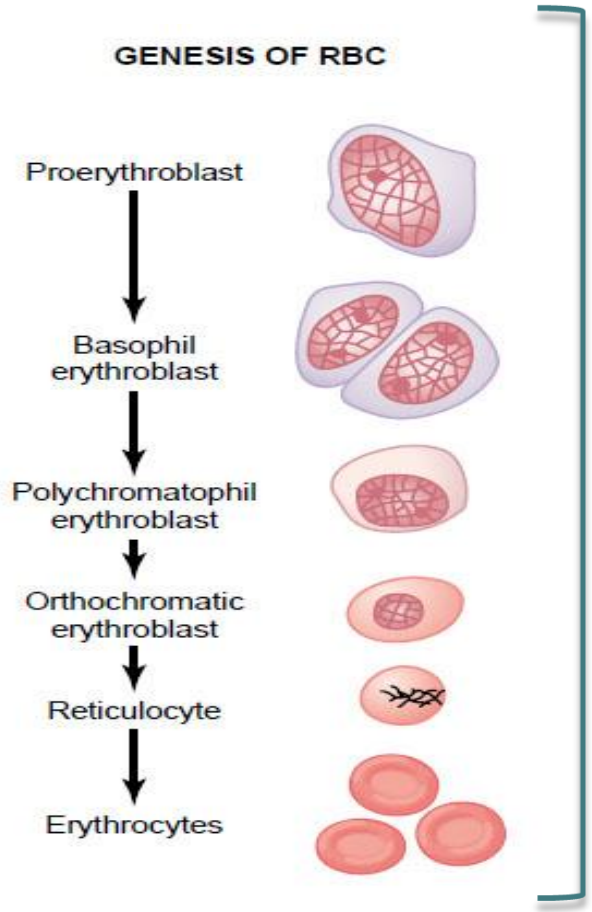


- **All blood cell are formed from Pluripotential hematopoietic stem cells ⇒ committed cells :**
  - **Committed stem cells for RBC**
  - **Committed stem cells for WBC**
- **Growth of different stem cells are controlled by different growth factors.**

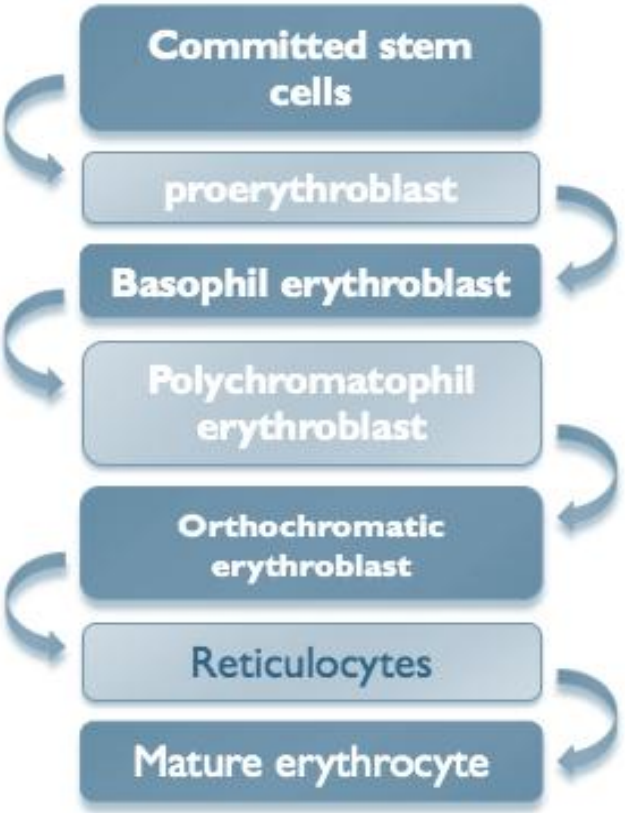
Pluripotential hematopoietic stem cells : the cells that give rise to all the other blood cells.

Contact us : Physiology435@gmail.com

Stages of differentiation of RBC



Stages of RBC development :



Note: RBC goes into stages to get its concave structure
reticulocyte is the stage where the cell loses its nucleus and is covered by a net.

Contact us : Physiology435@gmail.com

Erythropoiesis

RBCs development is characterize by :

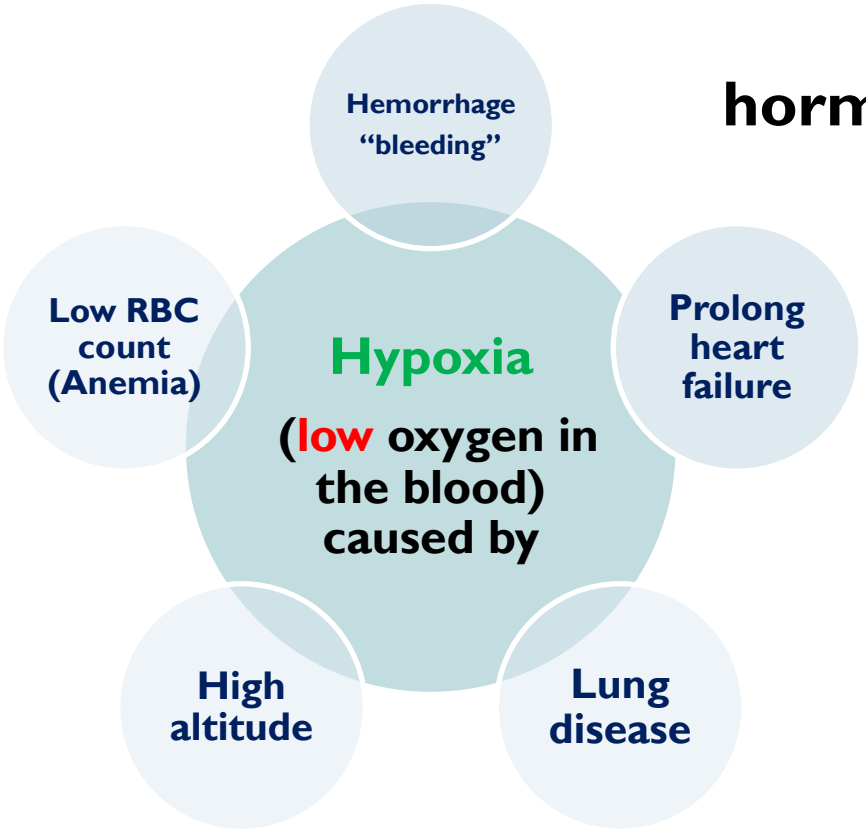
In cases of rapid RBC production : Reticulocytes increase in the ↑ circulation.

- **Decrease in cell size**
- **Disappearance of nucleus**
- **Appearance of hemoglobin (Hb)**

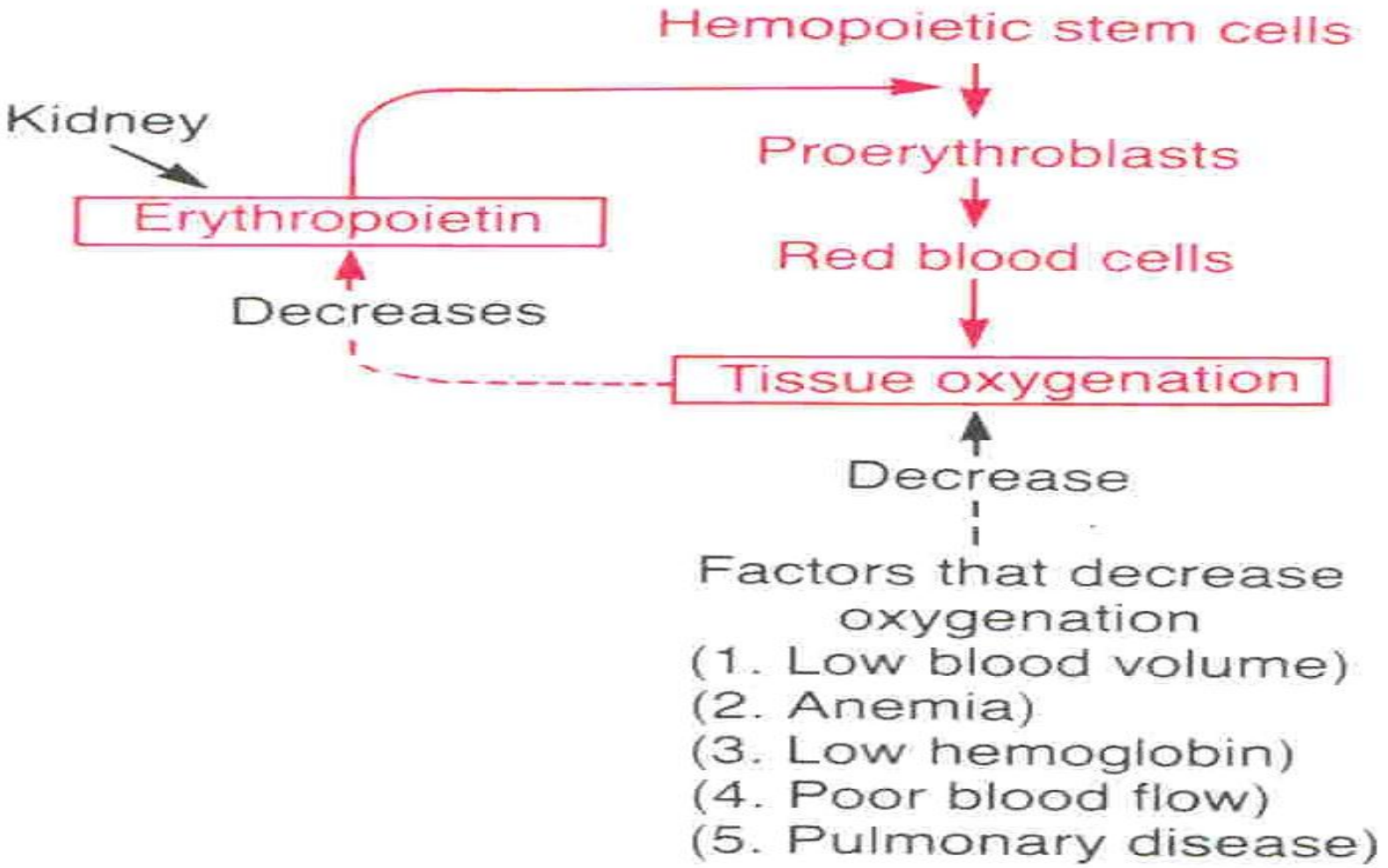
Contact us : Physiology435@gmail.com

Erythropoiesis

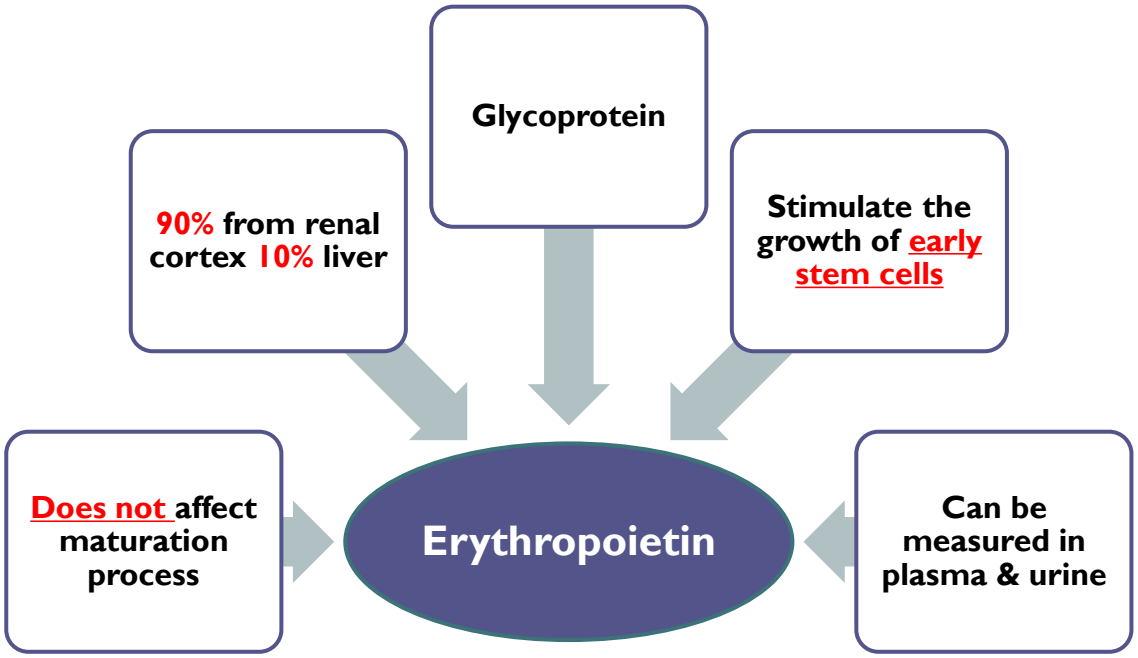
- **Erythropoiesis is stimulated by (Erythropoietin) which is: hormone produced by the kidney in response to Hypoxia**



Contact us : Physiology435@gmail.com


Hemopoietic stem cells
Kidney
Proerythroblasts
Erythropoietin
Red blood cells
Decreases
Tissue oxygenation
Decrease
Factors that decrease oxygenation
(1. Low blood volume)
(2. Anemia)
(3. Low hemoglobin)
(4. Poor blood flow)
(5. Pulmonary disease)

Erythropoietin " a hormone "



Conditions like:

- **Anemia.**
- **High altitude.**
- **Heart failure.**
- **Lung Disease.**

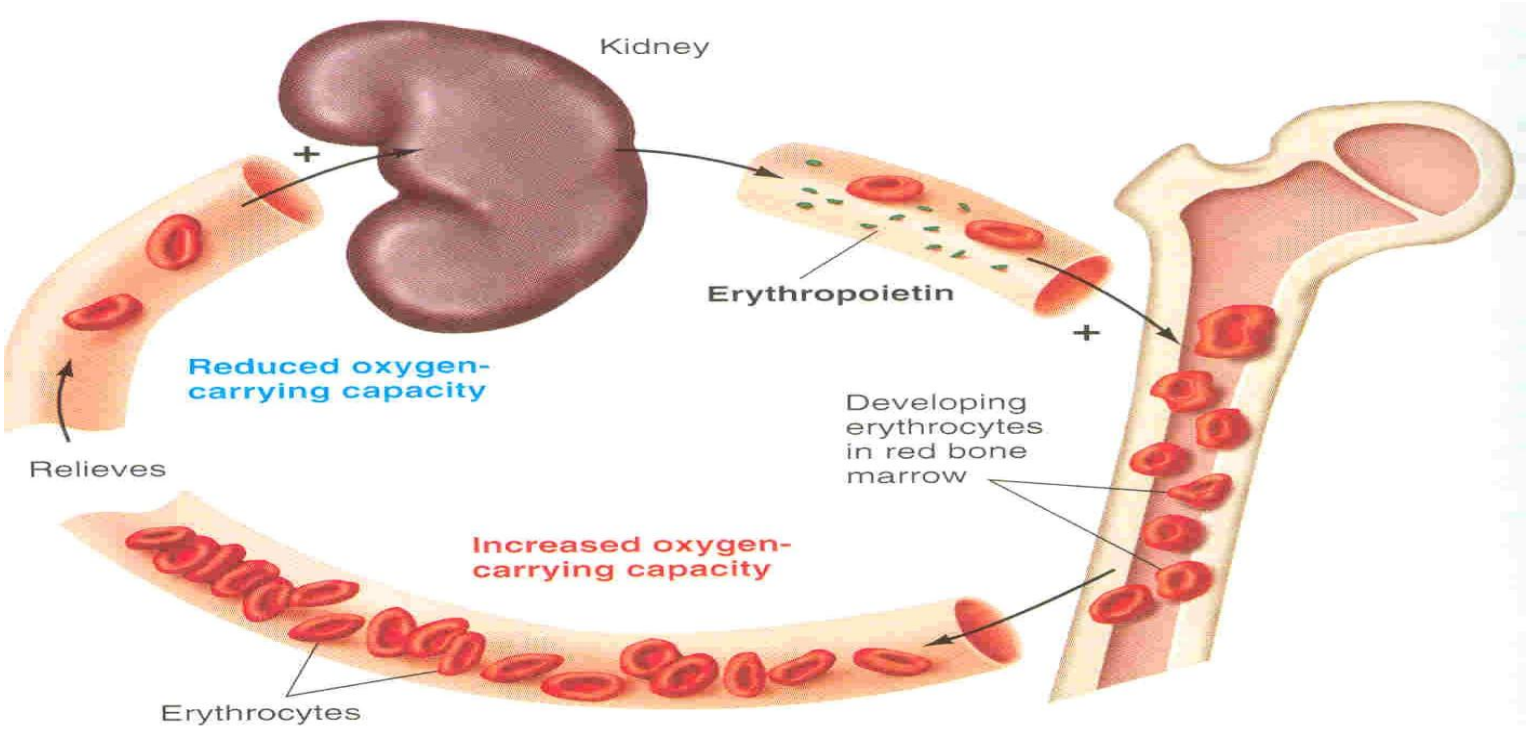
Result in High erythropoietin levels and polycythemia

Erythropoietin is a protein control the early stages of (red blood cells synthesis), but not the meddle or last stages.

Contact us : Physiology435@gmail.com

Role of the kidneys in RBC formation

Kidney produces erythropoietin in response to hypoxia



Healthy kidneys produce a hormone called erythropoietin and prompts the bone marrow to make red blood cells, which then carry oxygen throughout the body.

Contact us : Physiology435@gmail.com

	RBCs	WBCs	Platelets
Organelles	Lack nuclei and mitochondria	Have nucleus and mitochondria	Lack nuclei
Shape	Flattened biconcave disc	granular and non-granular (amoeboid*)	Irregularly shaped (amoeboid*)
Size	Diameter: 7-8um	Differ in sizes according to types	Diameter : 2-3um
Movement	Flexible	Diapedesis can "slip between " capillary wall	_____
Life span	120 days	Differ in life span according to types	5-10 days

Has irregular shape and usually move freely in blood

Contact us : Physiology435@gmail.com

Summary

Mind Map

Plasma = 55% of whole blood

98% water + ions + plasma proteins e.g. (Albumin, globulin, Fibrinogen)

Blood Functions

- Transport (O2, CO2, nutrient, hormones, waste product)
- Homeostasis (Regulation of body temperature, ECF pH)
- Protecting against infection
- Blood clotting prevent blood loss (White Blood Cells, Antibodies)

45% RBCs Erythrocytes

1% buffy coat

Packed cell volume , or hematocrit

Platelets Thrombocytes

WBCs Leucocytes

Blood composition

Blood PHYSIOLOGY

Red Blood Cells

Tissue oxygenation and RBC formation

Regulation of RBC production

Shape & size

Production of RBC

Stages of differentiation of RBC

Flat Biconcave Disc
Non-nucleated
Diameter 7-8 mm x 2.5 mm , 1 mm
Flexible
Number = 4.7 to 5 x10^6

In-utero

Early few weeks of embryo nucleated RBCs are formed in *yolk sac*

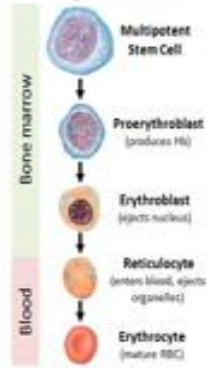
Middle trimester mainly in *liver & spleen & lymph nodes*

Last months RBCs are formed in *bone marrow* of all bones

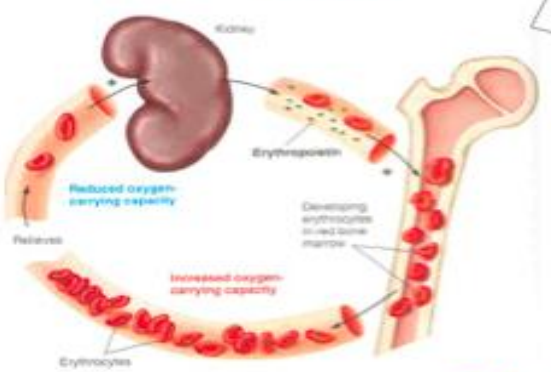
After Birth

Bone marrow of flat bone continue to produce RBC into adult life

Shaft of long bone stop to produce RBC at puberty while epiphysis continued



Role of the kidneys in RBC formation



Note : use this mind map for revision not studying cuz not all the info included !

Contact us : Physiology435@gmail.com

9 Blood physiology 2

- Very important
- Extra information
- Terms

(وَفِي أَنْفُسِكُمْ أَفَلَا تُبْصِرُونَ)[سورة الذاريات الآية:٢١]

Contact us : Physiology435@gmail.com

Objectives :

By the end of this lecture you should be able to:

- Describe essential elements needed for RBC formation.
- Describe the process of Vit B12 absorption and its malabsorption.
- Recognize hemoglobin structure and its functions.
- Discuss iron metabolism (absorption, storage and transport).
- Describe the fate of old RBC.
- Describe anemia and its causes.
- Recognize causes of polycythemia.

Contact us : Physiology435@gmail.com

Essential elements for RBCs formation and Maturation:

Amino acids:	Formation of globin in hemoglobin	sever protein deficiency → Anemia
Iron:	Formation of hemoglobin	Deficiency → Anemia
Vitamins:	Vit B12 and Folic acid Synthesis of nucleoprotein	Deficiency → Anemia
Hormones	Androgens, Thyroid, cortisol & growth hormones	Deficiencies of any one results in Anemia
Essential elements	Copper, Cobalt, zinc, manganese	

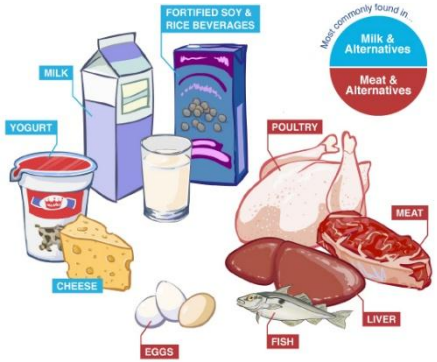
Other :Vit B6, Riboflavin, nicotinic acid, biotin, Vit C, Vit E

Contact us : Physiology435@gmail.com

Vitamin B12 & Folic acid

Dietary resources:

meat, milk, liver, fat, green vegetables.



Important for :

Important for DNA synthesis and final maturation of RBC.

Deficiency leads to:

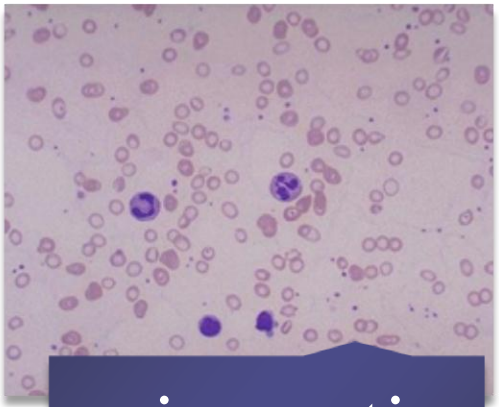
- Failure of nuclear maturation & division
- Abnormally large & oval shape RBC
- Short life span
- reduced RBC count & Hb
- Macrocytic (megaloblastic) anemia

Note: macrocytic : the cell becomes big and it won't divide.

Contact us : Physiology435@gmail.com

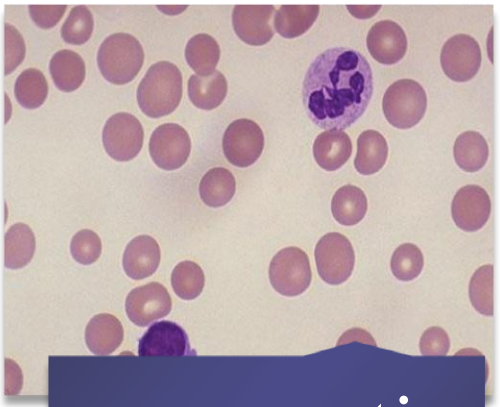
Types of anemia

- **Depends on the shape of the RBCs :**



microcytic

The RBCs are **small** in size



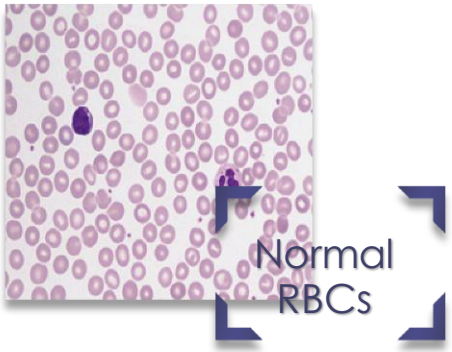
macrocytic

The RBCs are **large** in size

There's another type called : Sickle anemia
Which the shape of RBCs change to a sickle خلايا الدم المنجلية

Contact us : Physiology435@gmail.com

Types of anemia



- There is also increased **anisocytosis** (variation in size) and **poikilocytosis** (variation in shape).

microcytic

- **RBCs are smaller than normal**
- **Have an increased zone of central pallor**
- **Hypochromic** (less hemoglobin in each RBC)

Macrocytic

- **Hyper segmented neutrophil**
- **RBCs are larger than normal RBCs are almost as large as the lymphocyte.**
- **There are fewer RBCs**

Contact us : Physiology435@gmail.com

Malabsorption of Vit.b12

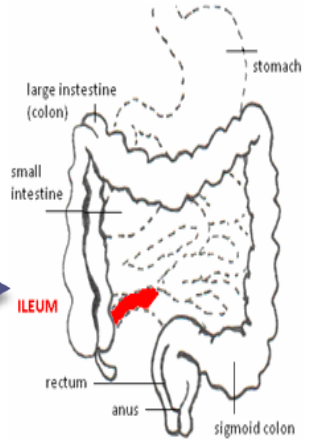
Pernicious Anemia

VB12 absorption needs **intrinsic factor** secreted by parietal cells of stomach

خلايا جدار المعدة

VB12 + intrinsic factor is absorbed in the

terminal Ileum.



Deficiency arise from (Causes of deficiencies):

Inadequate intake

Poor absorption due to **Intestinal disease**

Pernicious Anemia in a video

Contact us : Physiology435@gmail.com

Mal-absorption :
سوء أو خلل في الامتصاص

Iron

Iron metabolism (Fe)

- total iron in the body = 4-5 g
- 65% hemoglobin
- 5% other hems
- 1% bound to transferrin (betaglobulin) in blood
- 15-30% stored iron in the form of ferritin in the liver, spleen and bone marrow

Iron is needed for the synthesis of hemoglobin, myoglobin cytochrome oxidase, peroxidase & catalase.

Iron Absorption (Fe)

- Iron in food mostly in oxidized form (Ferric , F^{+3})
- Better absorbed in reduced form (Ferrous , F^{+2})
- Iron in stomach is reduced by gastric acid, Vitamin C.
- Rate of iron absorption depend on the amount of iron stored

Contact us : Physiology435@gmail.com

Transport and storage of iron

- Iron is transport in plasma in the form of **Transferrin** (apotransferrin + iron)

- Iron is stored in two forms:

  - **Ferritin** (apoferritin + iron)
  - **Hemosiderin** (insoluble complex molecule, in liver, spleen, bone marrow)

- Daily loss of iron is 0.6 mg in male & 1.3 mg/day in females

Transferrin in a video

Contact us : Physiology435@gmail.com

Destruction of RBC

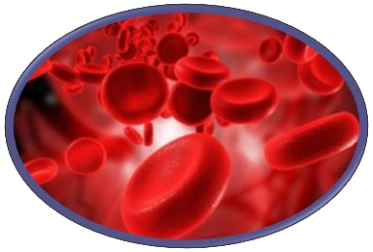
RBC life span in circulation = 120 days

Metabolic active cells

Old cell has a fragile cell membrane, cell will rupture as it passes in narrow capillaries and spleen

Released Hb is taken up by macrophages in liver, spleen & bone marrow:

Hb is broken into its component:

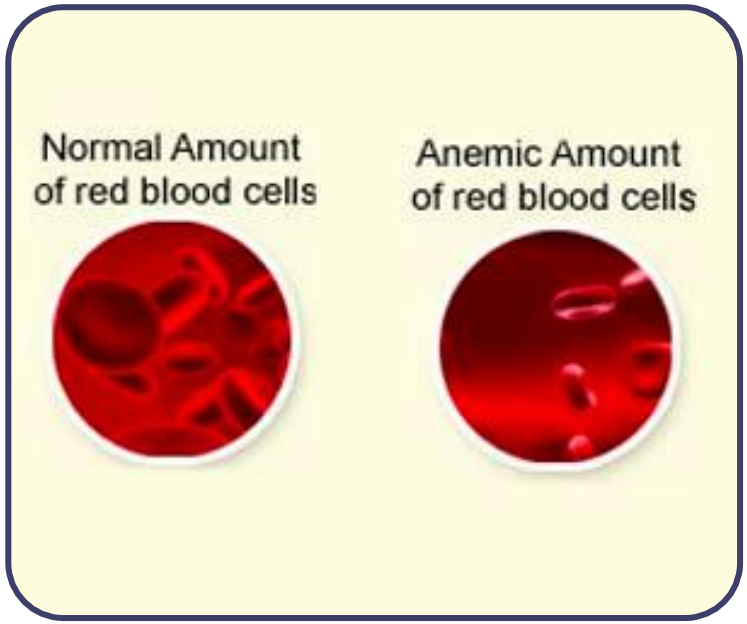


-Polypeptide —amino acids
(protein pool = storage)
-Iron ---- ferritin
-Haem (Porphyria)→ bilirubin → secreted by the liver into bile.
[excess destruction of RBC Jaundice]

Contact us : Physiology435@gmail.com

Anemia

- **Definition :**
  - Decrease number of RBC.
  - Decrease Hb (Hemoglobin).
- **Symptoms :**
  - Tired , Fatigue , short of breath and heart failure.



Contact us : Physiology435@gmail.com

Causes of anemia

Blood Loss	Decrease RBC production	Hemolytic (Excessive destruction)
▪ **Acute :** ➡ accident (RBC return to normal 3-6 w) ▪ **Chronic :** ➡ microcytic hypochromic anemia (ulcer, worms)	▪ **Nutritional causes :** - Iron : ➡ microcytic Hypochromic anemia - Vit B12 & Folic acid : ➡ megaloblastic anemia . ▪ **Bone marrow failure :** destruction by cancer, radiation, drugs Aplastic anemia.	▪ **Abnormal cells or Hb :** 1. Spherocytosis 2. sickle cells ▪ **Incompatible blood transfusion.** ▪ **Erythroblastosis fetalis**

Contact us : Physiology435@gmail.com

Polycythemia

Result

Increased number of RBCs

Types

1. Primary :

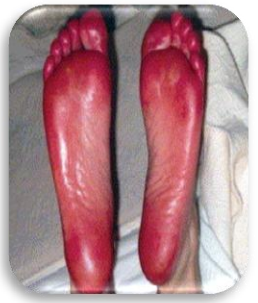
(Polycythemia Rubra Vera – PRV):

uncontrolled RBC Production. video

2. Secondary :

to hypoxia : high altitude(physiological), chronic respiratory or cardiac disease

video



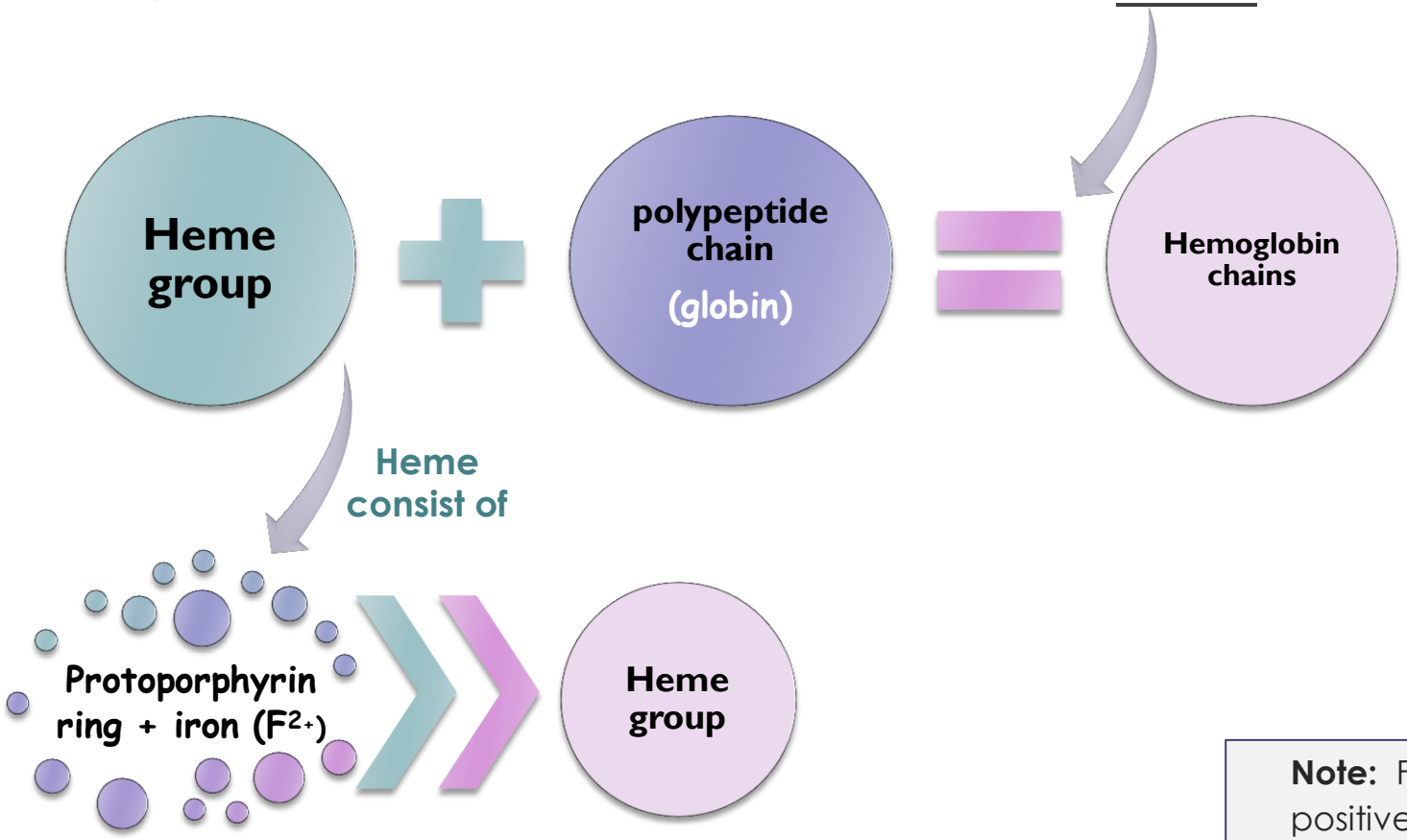
Note: primary: unknown reason

- Polycythemia : increase in RBCS , while Anemia is decreased in RBCs

Contact us : Physiology435@gmail.com

Structure of HAEMOGLOBIN

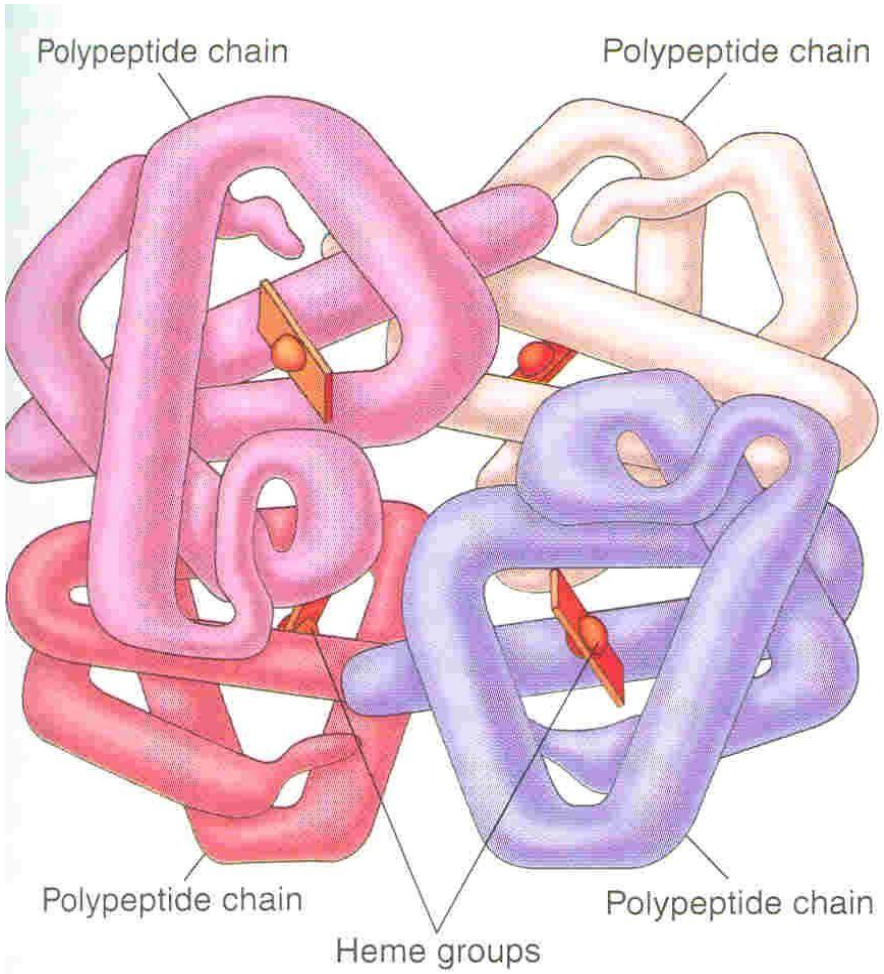
- Hb molecules consist 4 chains each chain formed of

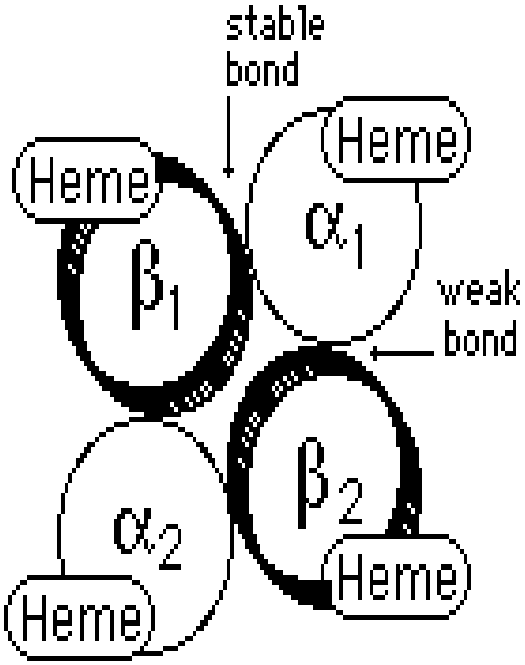


Note: F^{+2} ➡ the positive 2 means that it is holding 2 oxygen

Contact us : Physiology435@gmail.com

Structure of hemoglobin





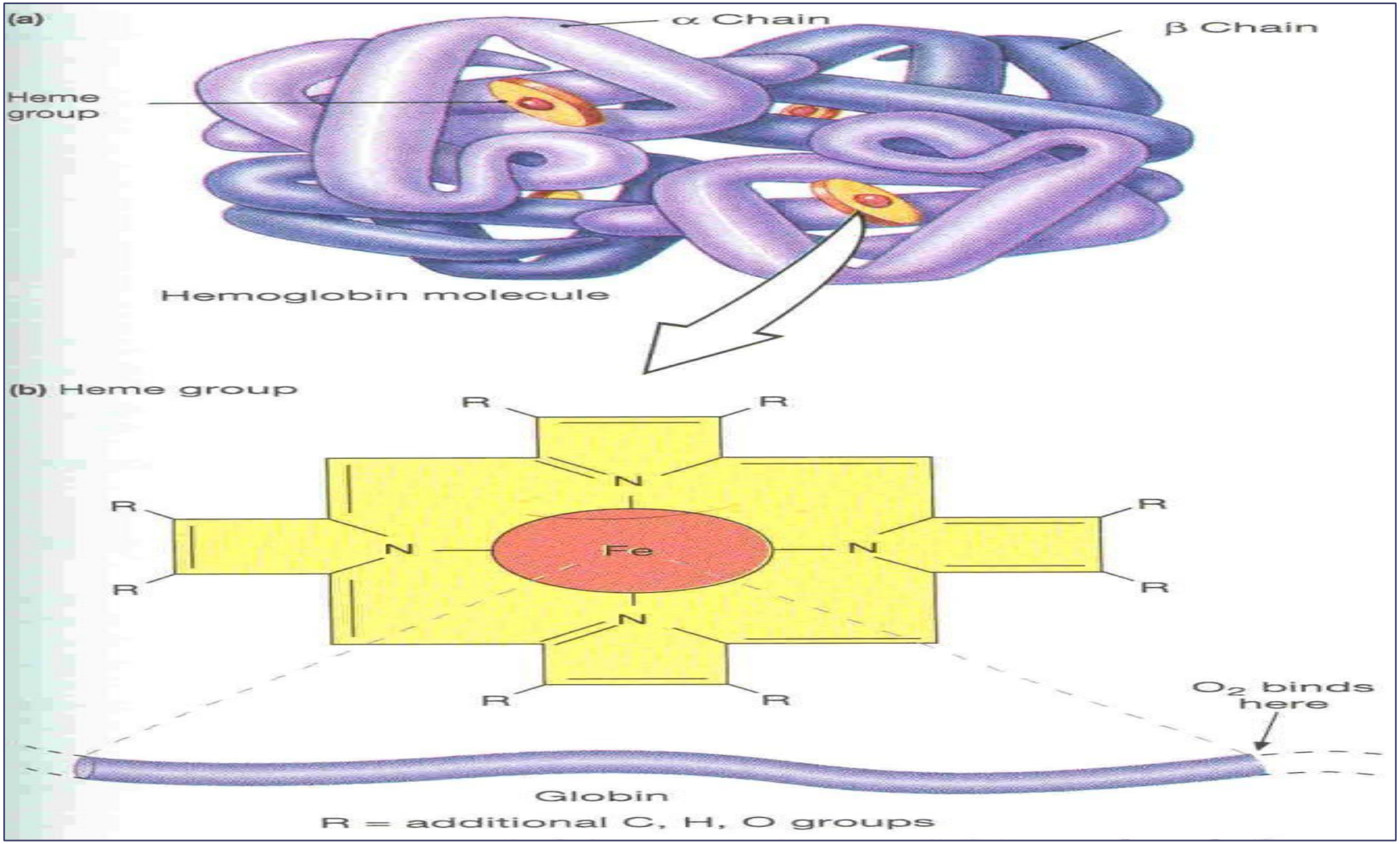
Contact us : Physiology435@gmail.com

Types of HB

- **Normal**
  - **Hb A** (2 alpha & 2 beta chains) (adult Hb) **(98%).**
  - **Hb A2** (2 alpha & 2 delta chains) **(2%)**
  - **Hb F** (2 alpha & 2 γ "gamma" chains) (Hb of intrauterine life).
- **Abnormal**
  - **Abnormality in the polypeptide chain**
  - **abnormal Hb (Hemoglobinopathies)**
    - **e.g. thalassemia, sickle cell (HBS).**

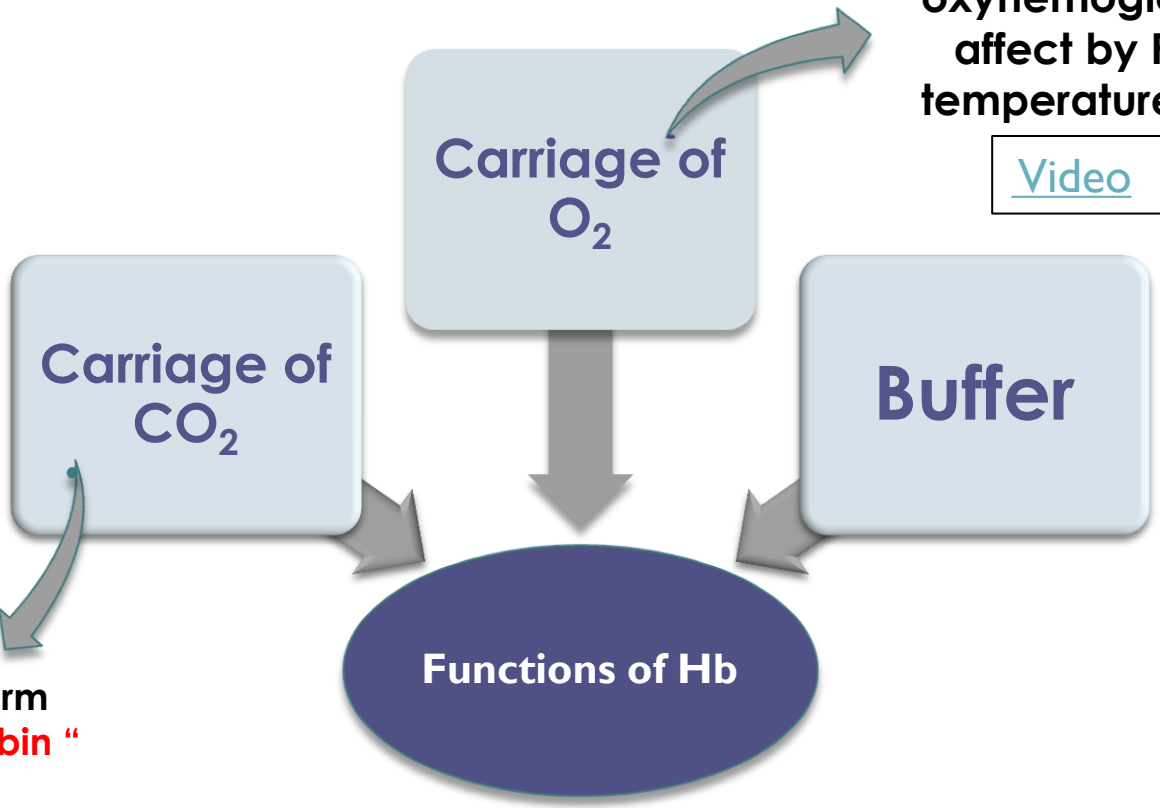
Note: Hb F has high affinity to oxygen than Hb A

Thalassemia :
video1 , video2
Types of Hb



Contact us : Physiology435@gmail.com

Functions of hemoglobin



Hb reversibly bind O_2 to form " oxyhemoglobin " affect by PH, temperature, H^+

Video

Hb bind CO_2 to form " carboxyhemaglobin "

Check your understanding : Quiz

Videos :

Red blood cell life cycle

How are Red Blood Cells made? Erythropoiesis - Erythropoietin – Regulation

Anemia

Macrocytic Anemia & Microcytic Anemia

Hemoglobin Structure

التبرع بالدم ينشط خلايا نخاع العظم للمتبرع مما يزيد فاعليتها
ويجدد نشاطها فتنتج المزيد من خلايا الدم الجديدة فبينما يتجدد دم
الإنسان كل ١٢٠ يوم فإن دم المتبرع يتجدد كل ٢٠ يوم !

Contact us : Physiology435@gmail.com

Summary

A

Mind Map

Vit B 12 and folic acid :
a) synthesis of nucleoprotein
b) deficiency leads to anaemia
Other : Vit B6 , Ribofalvin , nicotinic acid ,biotin , Vit C , Vit E

Copper , cobalt , zinc ,manganese

* Androgens , Thyroid , cortisol & growth hormones
* Deficiency of any one results in anaemia

3- Vitamins

4- Essential elements

5- Hormones

deficiency leads to anaemia

2- Iron : formation of haemoglobin

Essential elements for RBCs formation and Maturation

1- Amino acids formation of globin in haemoglobin

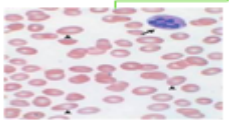
Sever protein deficiency leads to anaemia

Structure of haemoglobin

Each erythrocyte (RBC) contains ~270 million haemoglobin molecules

Important for DNA synthesis and final maturation of RBC

Note the hyper segmented neutrophil and also that the RBC are almost as large as the lymphocyte.
Finally, note that there are fewer RBCs.

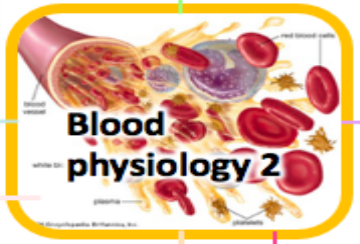


Dietary source: meat, milk, liver, fat, green vegetables

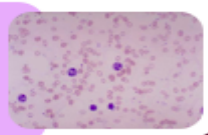
Vitamin B12 & folic acid

Deficiency leads to:

- Macrocytic (megaloblastic) anemia
- Failure of nuclear maturation & division
- Short life span
- reduced RBC count & Hb
- Abnormally large & oval shape RBC



Microcytic hypochromic anaemia

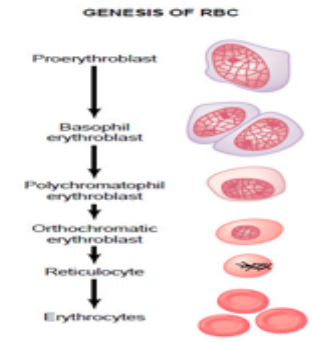


* There is also increased anisocytosis (variation in size) and poikilocytosis (variation in shape).

* The RBC's are smaller than normal and have an increased zone of central pallor.

* This is indicative of a microcytic (smaller size of each RBC) and hypochromic (less hemoglobin in each RBC) anemia

Stages of differentiation of RBC



Malabsorption of Vit. B12

Pernicious Anemia

- Absorption needs intrinsic factor secreted by parietal cells of stomach
- VB12 + intrinsic factor is absorbed in the terminal Ileum.
- Deficiency arise from (Causes of deficiencies):
  *Inadequate intake
  *Poor absorption due disease to Intestinal

Iron metabolism (Fe)

Iron is needed for the synthesis of haemoglobin, myoglobin cytochrome oxidase, peroxidase & catalase

*Total Iron in the body = 4-5g

65% ..... Haemoglobin

5% ..... other hems

1% .... bound to transferrin (betaglobulin) in blood

15-30% ..... stored iron in the form of ferritin in the liver, spleen and bone marrow.

Note :

*** This mind map includes slides 1-14**

*** Use it for revision not studying because not all the info included**

Contact us : Physiology435@gmail.com

Summary

B

Mind Map

Note : * This mind map includes slides 15-25
* Use it for revision because not all the info is included

Iron absorption

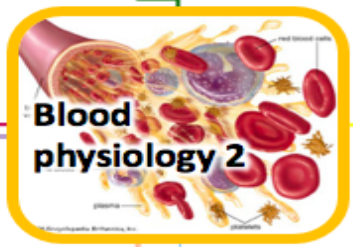
- Iron in food mostly in **oxidized** form (Ferric, F+3) **Better absorbed** in reduced form (Ferrous, F+2)
- Iron in stomach is **reduced** by gastric acid, Vitamin C
- Rate of iron **absorption** depend on the **amount of iron stored**

Iron is transport in plasma in the form of Transferrin **(apotransferrin + iron)**

Transport and storage of iron

Iron is stored in two forms

- *Ferritin (apoferritin + iron)
- * Hemosiderin (insoluble complex molecule, in liver, spleen, bone marrow)
- * Daily loss of iron is 0.6 mg in male & 1.3mg/day in females.

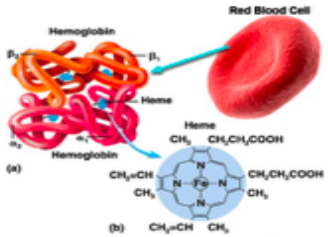


Destruction of RBC

- RBC life span in circulation = **120 days.**
- Metabolic active cells.
- Old cell has a fragile cell membrane, cell will rupture as it passes in narrow capillaries (and spleen).
- Released Hb is taken up by macrophages in liver, spleen & bone marrow:
  Hb is broken into its component
- Polypeptide—amino acids (protein pool = storage)
- Iron ---- ferritin

Haem (Porphyrin)>>—bilirubin>>—secreted by the liver into bile. [excess destruction of RBC Jaundice]

) Polycythemia (Increased number of RBC



Haemoglobin

- compositions
- Types
- functions

ANAEMIAS

Causes of anaemia

3.Haemolytic → excessive destruction

- Abnormal cells or Hb
  - •Spherocytosis
  - •sickle cells
- Incompatible blood transfusion.
- Erythroblastosis fetalis .

2.Decrease RBC production

Nutritional causes

- Iron → microcytic hypochromic anaemia.
- Vit B12 & Folic acid →megaloblastic anaemia

Bone marrow failure: destruction by cancer, radiation, drugs Aplastic anaemia

1.Blood Loss

a. Acute

accident (RBC return to normal 3-6w)

b. Chronic

microcytic hypochromic anemia (ulcer, worms)

Definition

Decrease number of RBC

Decrease Hb

Symptoms:

Tired, Fatigue, short of breath, heart failure

Contact us : Physiology435@gmail.com

Physiology team

خولة العماري
الهنوف الجلعود
إلهام الزهراني
رغد النفيسة
نورة القحطاني
منيرة الحسيني
منيرة السلولي
ريم البهلال
عريب العقيل
ملاك الشريف
منيال باوزير
فتون الصالح
أفنان المالكي
ربى السليمي

عمر العتيبي
رواف الرواف
حسن البلادي
عمر الشهري
عادل الشهري
عبدالله الجعفر
عبدالرحمن البركة
محمد الشيباني
خليل الدريبي
عبدالعزيز الحماد
عبدالعزيز الغنايم
عبدالمجيد العتيبي

Contact us : Physiology435@gmail.com