



Hematopoiesis

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Chromatin

Formed of DNA.

• 2 Forms:

- Euchromatin: extended active → allows transcription chromatin (pale).
- Heterochromatin: condensed inactive chromatin (dark) → electron dense, usually condensed at peripheral part of nucleus

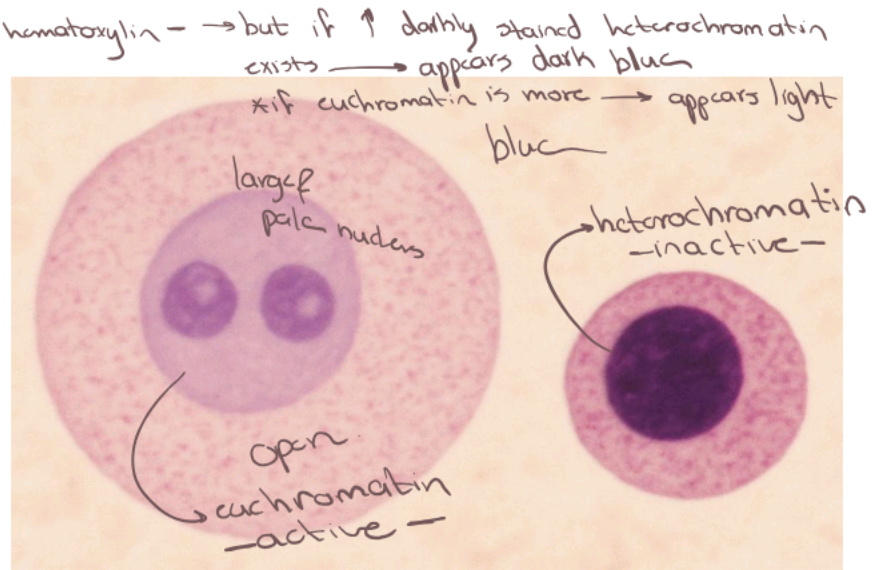
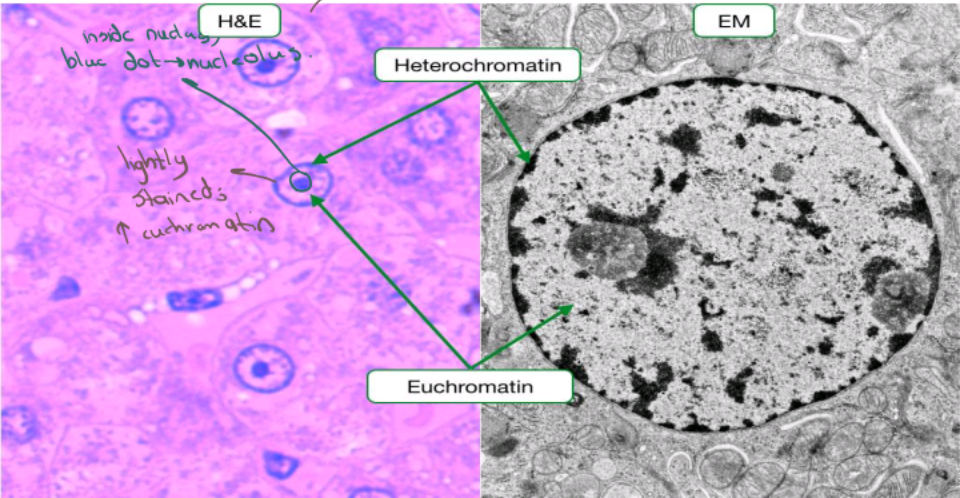
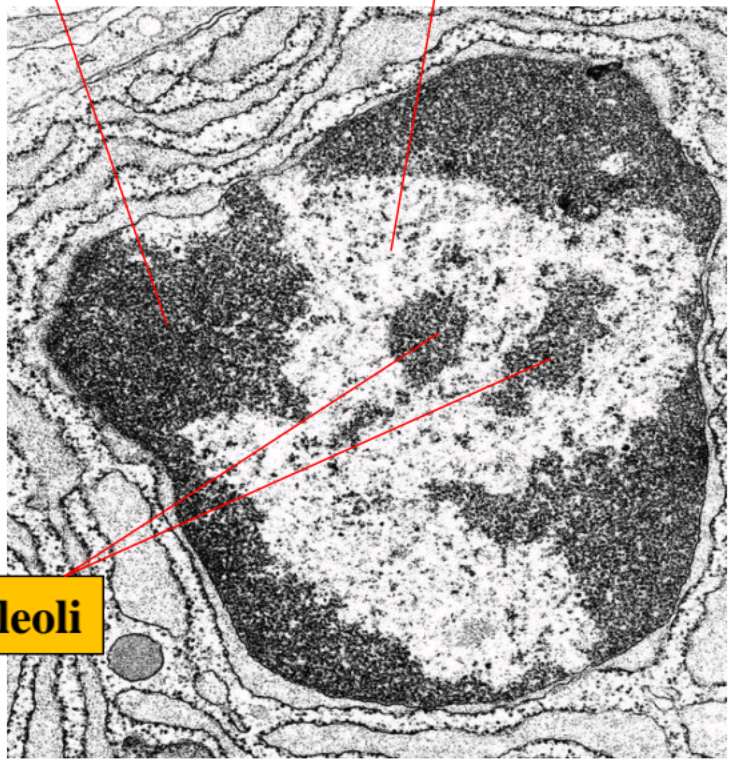
Nucleolus

- It is a spherical dark basophilic mass not surrounded by a membrane.
- Usually one. → prominent nucleolus indicates protein synthetic activity of the cell
- Function: formation and assembly of ribosomal RNA (rRNA), which is responsible for protein synthesis in the cytoplasm

Heterochromatin

Euchromatin

Nucleoli

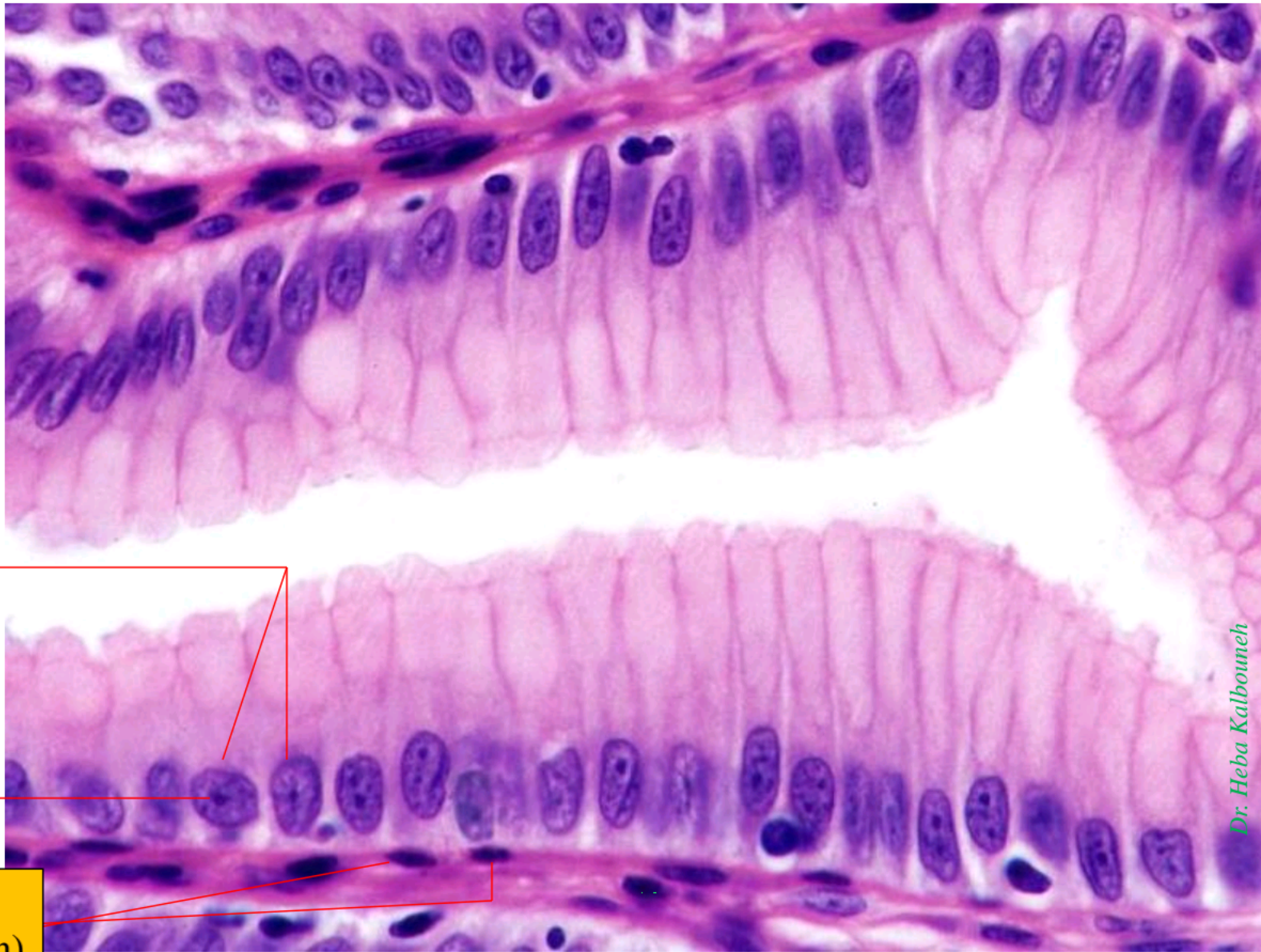


Note:

The nucleus stains **blue (basophilic)** using H&E

Lightly basophilic: active

Deeply basophilic and small: inactive



Active nucleus
(Euchromatin)

Nucleolus

Inactive nuclei
(Heterochromatin)

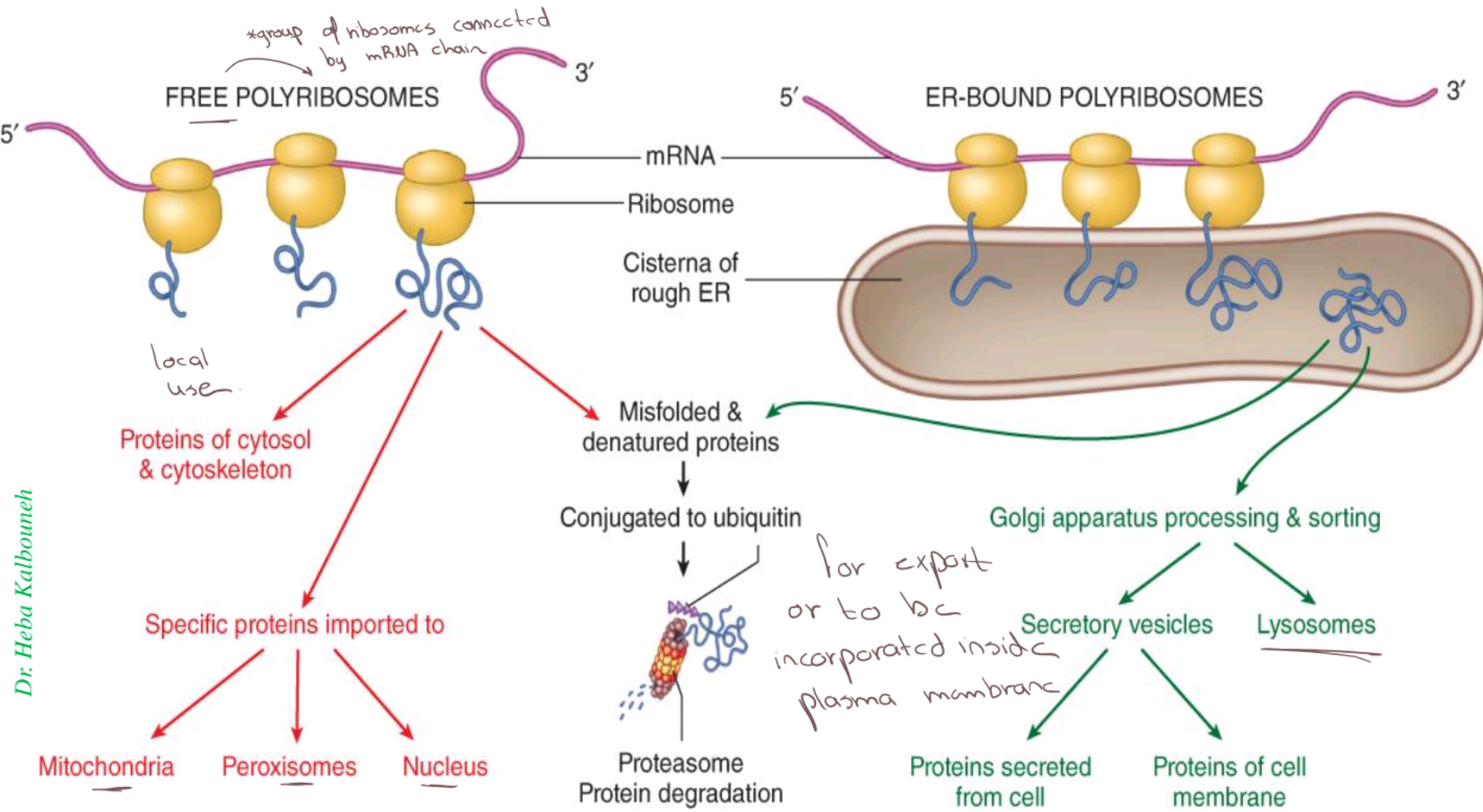
Note:

The cytoplasm stains **pink/red (acidophilic)** using H&E

The organelle (when prominent) that produces **basophilia** in the cytoplasm is the

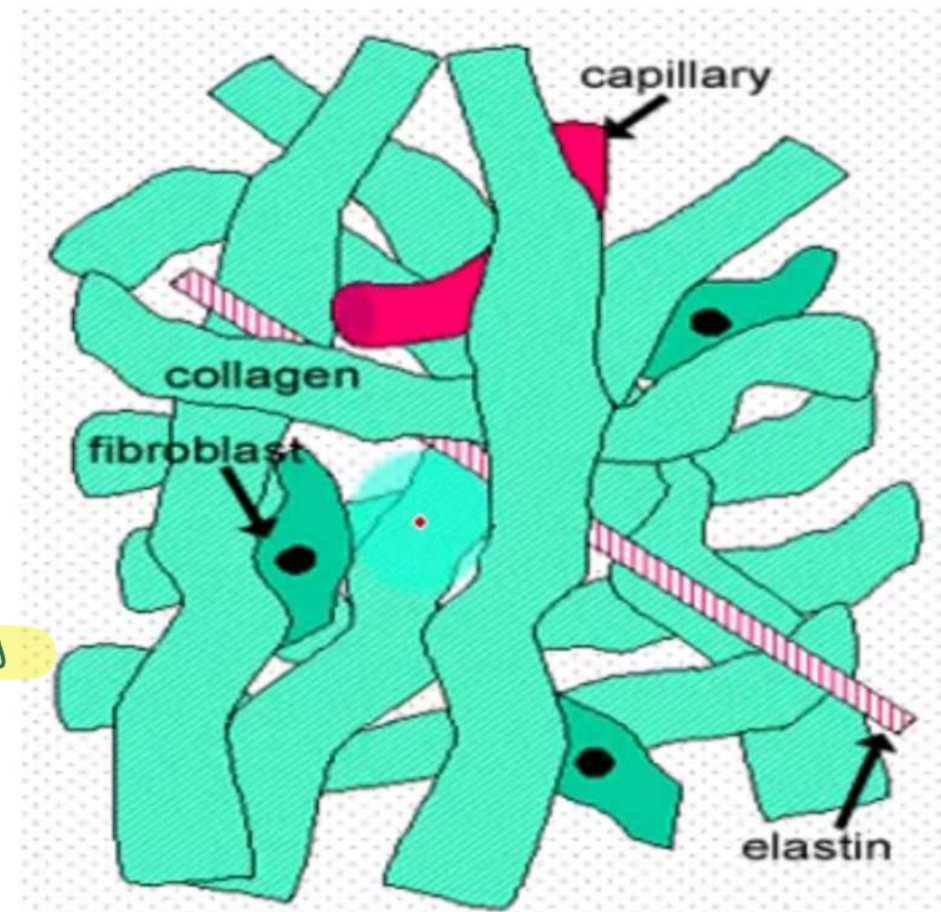
ribosome → RBC

ribosomal rRNA,
negatively charged
-nucleic acid-



Dense irregular connective tissue

- ✓ Bundles of collagen fibers are randomly interwoven with no definite orientation
- ✓ Provides resistance to stress from all directions
- ✓ Dermis of skin (deeper layer), **organ capsules**, **submucosa**
 - * * *
 - lymphoid organs are capsulated

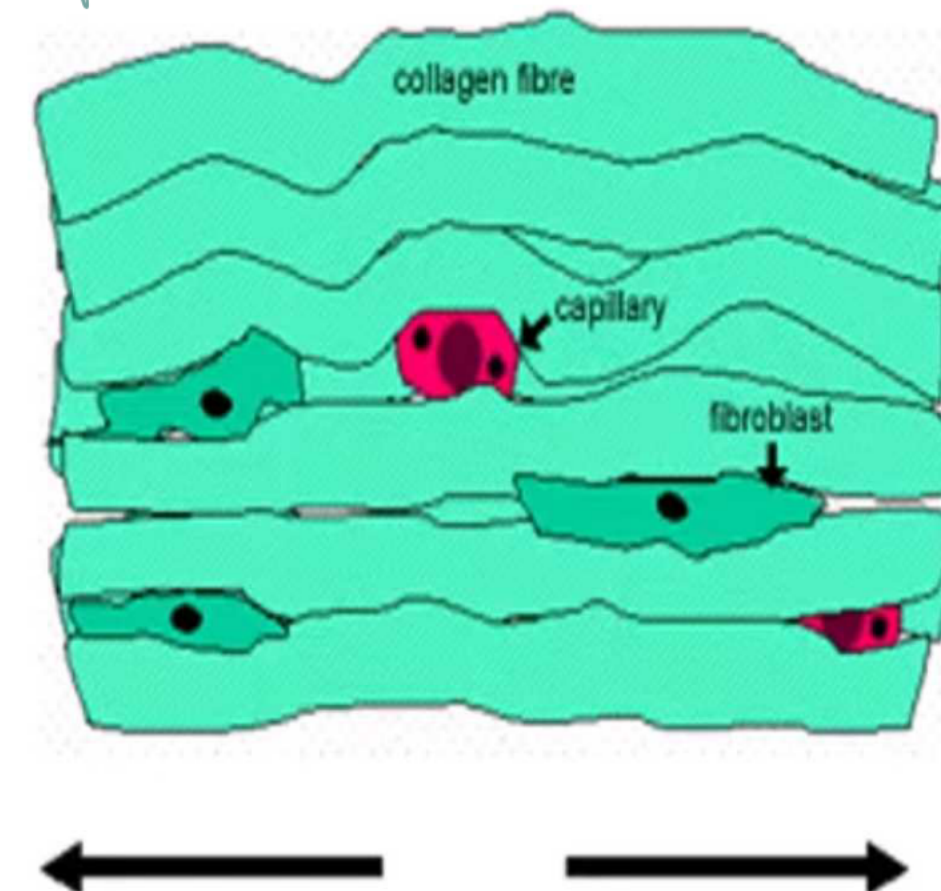


Connective tissue proper

- loose → cells, fiber, ground substance in same proportions
- dense → ↑ collagen Type I fibers
 - irregular → fibers > cells, ground substance
 - regular → based on orientation of collagen type I fibers.

Dense regular connective tissue

- ✓ Parallel Bundles of collagen fibers with few fibrocytes aligned with collagen and separated by very little ground substance



Stroma means bed

In all organs:-

main function of
↑ organ

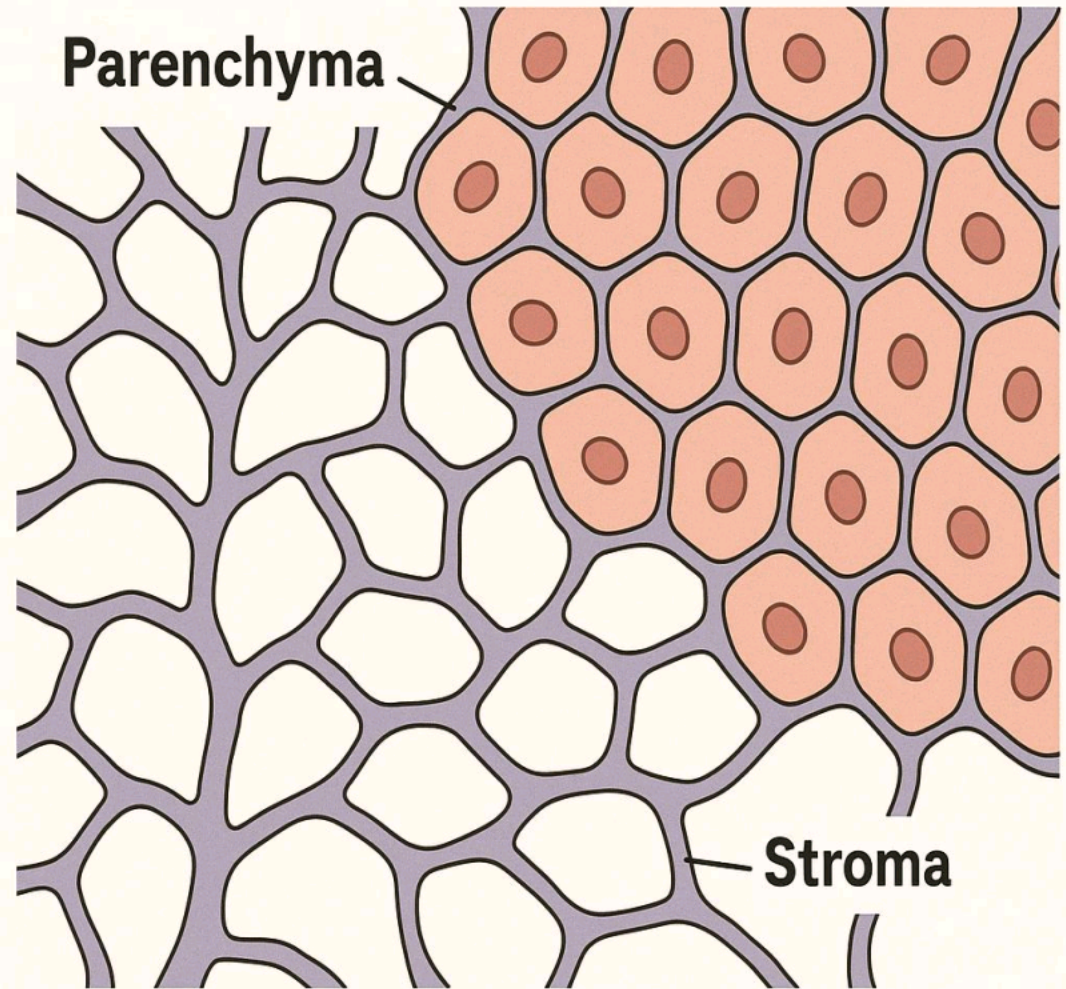
→ supporting tissue.

Parenchyma / Stroma:

The **parenchyma** of an organ consists of that tissue which conducts the specific function of the organ and which usually comprises the bulk of the organ. **Stroma** is everything else -- **connective tissue**, **blood vessels**, **nerves**, **ducts**. It is made up of all the parts without specific functions of the organ

For Example:

The *parenchyma* of the heart is **muscle tissue** (cardiac muscle cells). The nerves, intrinsic blood vessels, and connective tissue of the heart comprise the *stroma*.

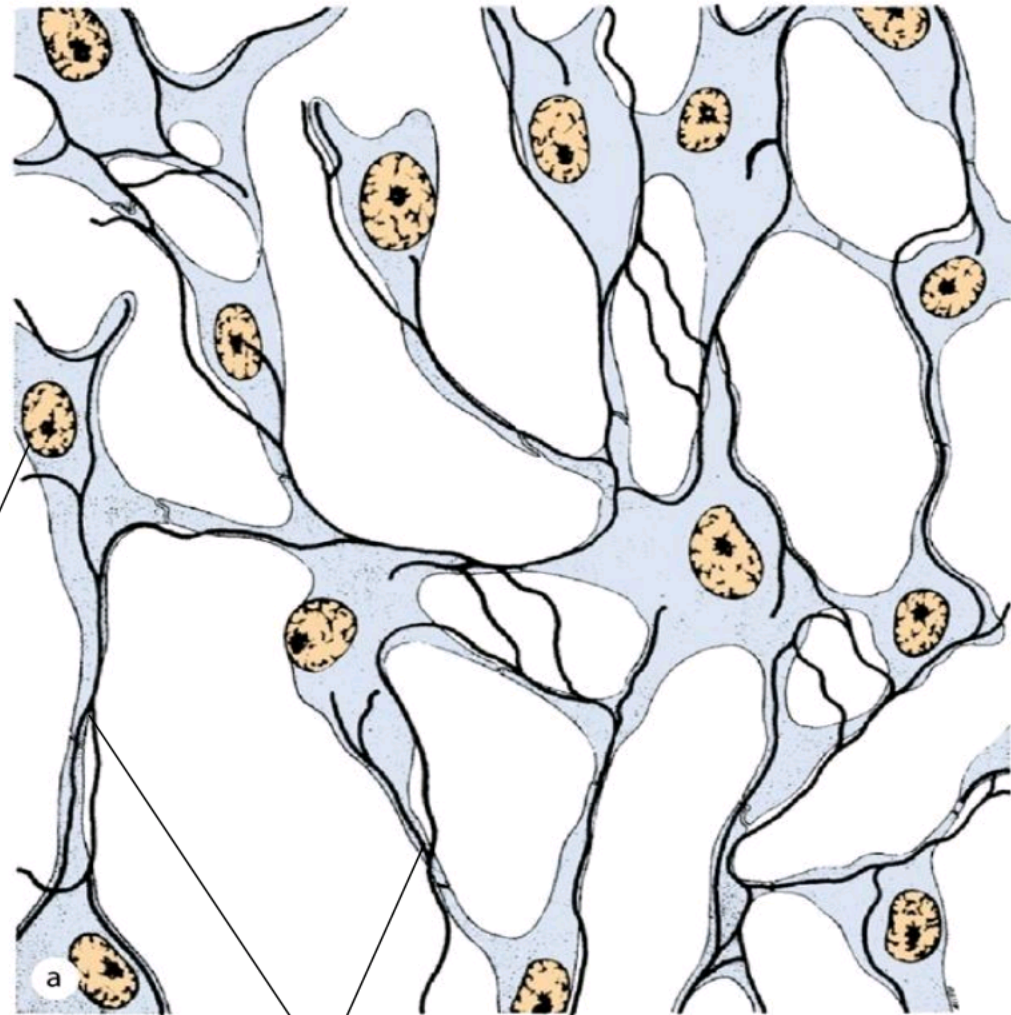


forms stroma
for certain
organs

Reticular connective tissue

- Consists of reticular cells (modified fibroblasts) and the network of reticular fibers formed by them
- Forms the structural framework (stroma) in which the cells of the organ are suspended
- In the **liver, bone marrow, lymph nodes and spleen** (**Reticulo-Endothelial organs**)

Type III
collagen
fibers.



Reticular cell

wide spaces fill with
blood or lymph -
lined with endothelium &
supported by
reticular tissue.

* Reticular fibers are thin and branching forming a network

↳ wide spaces to permit movement of large molecules or even cells.

Types of capillaries

Smallest blood vessel where fluid exchange takes place.

Continuous capillaries

- Are most common
- Endothelium forms solid lining
- Adjacent cells are held together with tight junctions
- Found in most organs
- supported by continuous layer of BM

Fenestrated capillaries

- Endothelium contains pores (fenestrations) *but BM continuous.*
- Found wherever active capillary absorption or filtrate formation occurs
- Found in endocrine glands, small intestine, and kidney

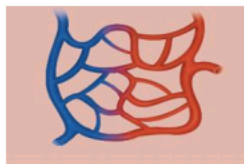
mass of epithelial cells & secretory tubules

absorption of nutrients

absorption of materials

Capillary

-no smooth muscles-



* Basement membrane

* Endothelial layer (tunica intima)

single layer

Intercellular cleft

Sinusoidal capillaries

large lumen

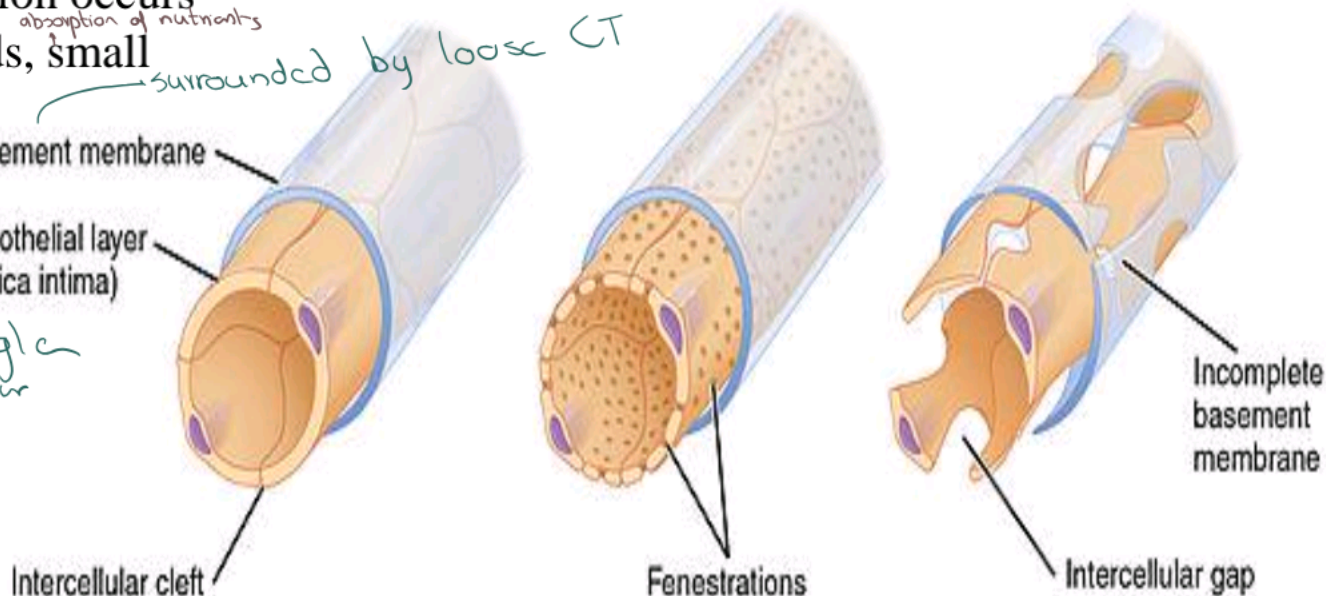
- Exhibit wide diameters with wide gaps between endothelial cells
- Basement membrane incomplete or absent
- Allow large molecules (proteins and blood cells) to pass between the blood and surrounding tissues
- Found in liver, spleen, and bone marrow

large plasma proteins

Continuous

Fenestrated

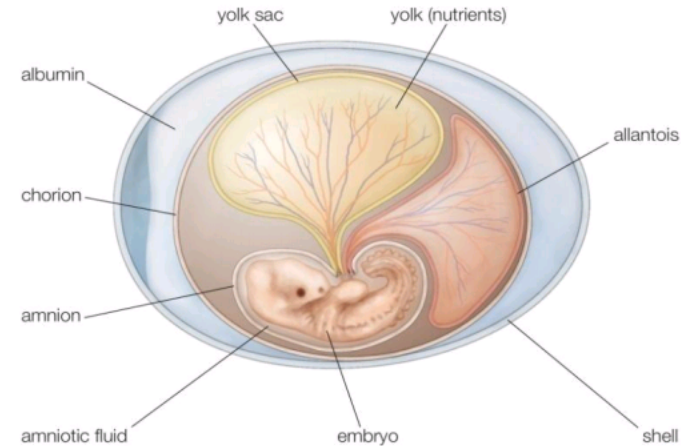
Sinusoid



Blood Cell Formation (Hematopoiesis)

Mature blood cells have a relatively short life span and must be continuously replaced with new cells from precursors developing during hemopoiesis/ hematopoiesis (Gr. haima, blood + poiesis, a making).

Amniotic egg



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→ hematopoietic stem cells

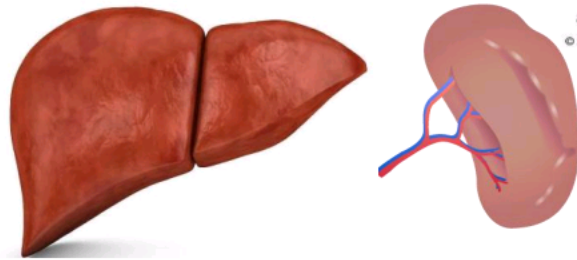
Early embryo ≈ 3rd week ⇒ HPSC appear for 1st time in yolk sac
Yolk sac mesoderm

Second trimester ≈ 3rd month
Developing liver and spleen

mainly → enlarged during fetal life

Third trimester

Bone marrow → stem cells migrate to bone marrow



After birth, all blood cells originate in bone marrow

Medullary hematopoiesis

↳ bone marrow

⇒ outside BM: extra-medullary BM ⇒ liver, spleen, yolk sac

Bone marrow

The **red bone marrow** is a highly cellular structure that is located in the medullary cavities of the bone

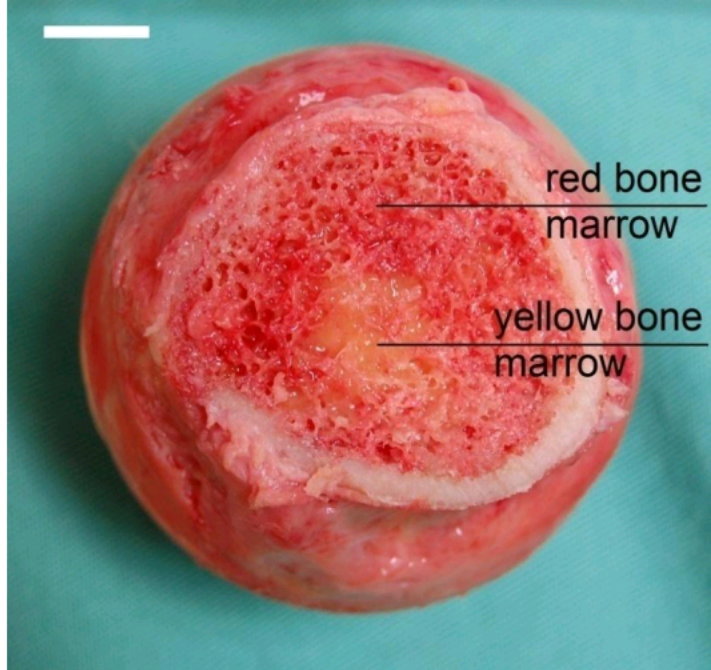
It consists of:

- * **Hemopoietic stem cells** (the origin of different blood cells) surrounded by numerous macrophages and sinusoidal capillaries and supported by a reticular tissue.



As the individual ages and becomes an adult, the red marrow is found primarily in the **axial skeleton** (flat bones of the skull, sternum and ribs, vertebrae, and pelvic bones). The remaining bones, primarily the long bones in the limbs of the body, gradually accumulate fat, and their marrow becomes yellow. Consequently, they lose the hemopoietic functions.

inactive in hematopoiesis
*yellow bone marrow is storage site for fat.
-large adipocytes - & small no. of HSPC.
can revert back to RBM

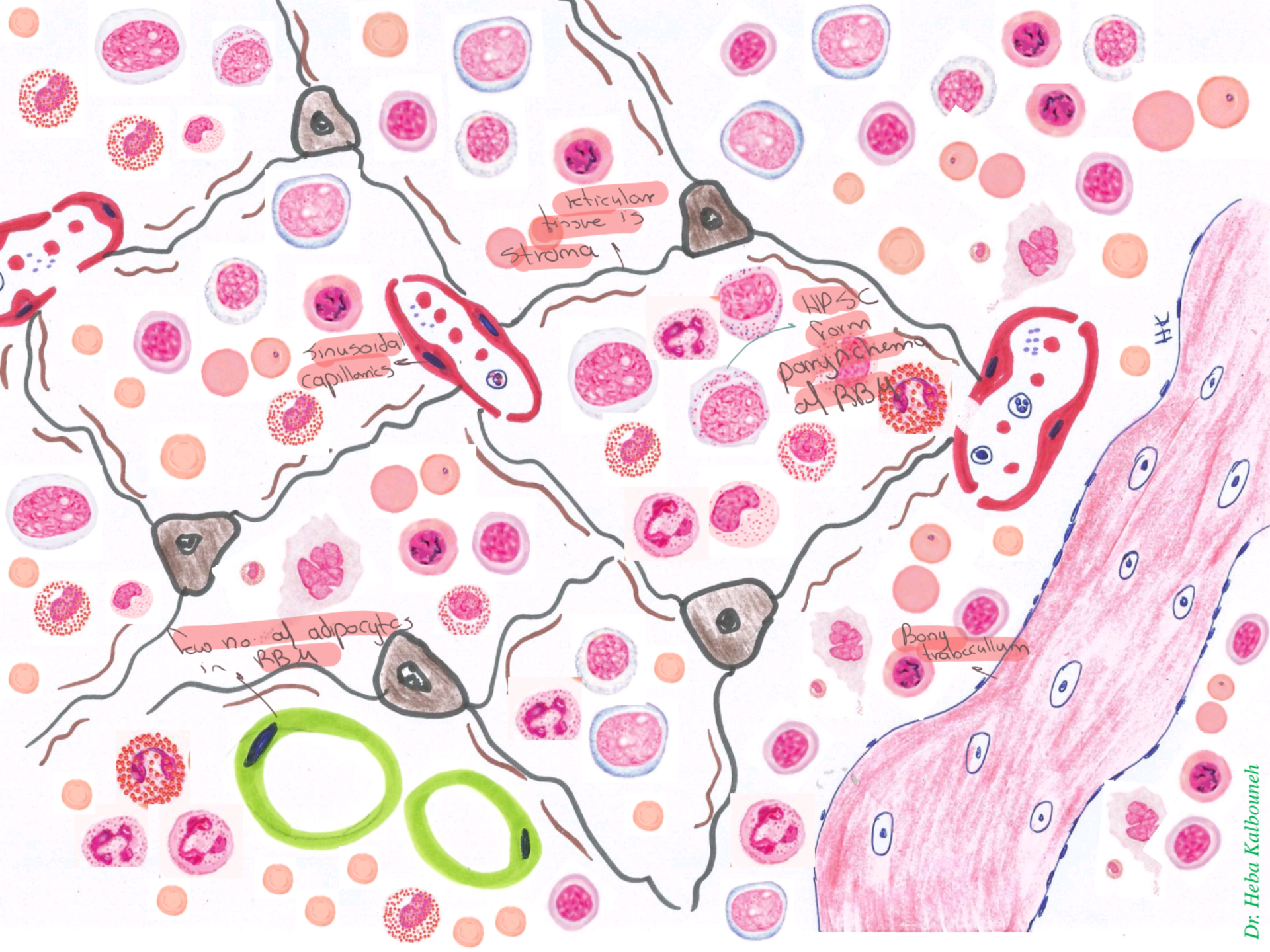


red bone marrow

yellow bone marrow

Extramedullary hematopoiesis refers to the hematopoiesis that occurs in organs other than bone marrow.
(fetal development, normal immune responses, and pathological circumstances)

- * Under certain conditions (severe bleeding or hypoxia), yellow marrow reverts to red



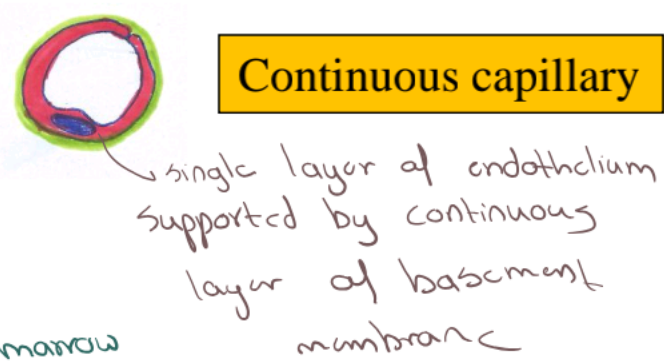
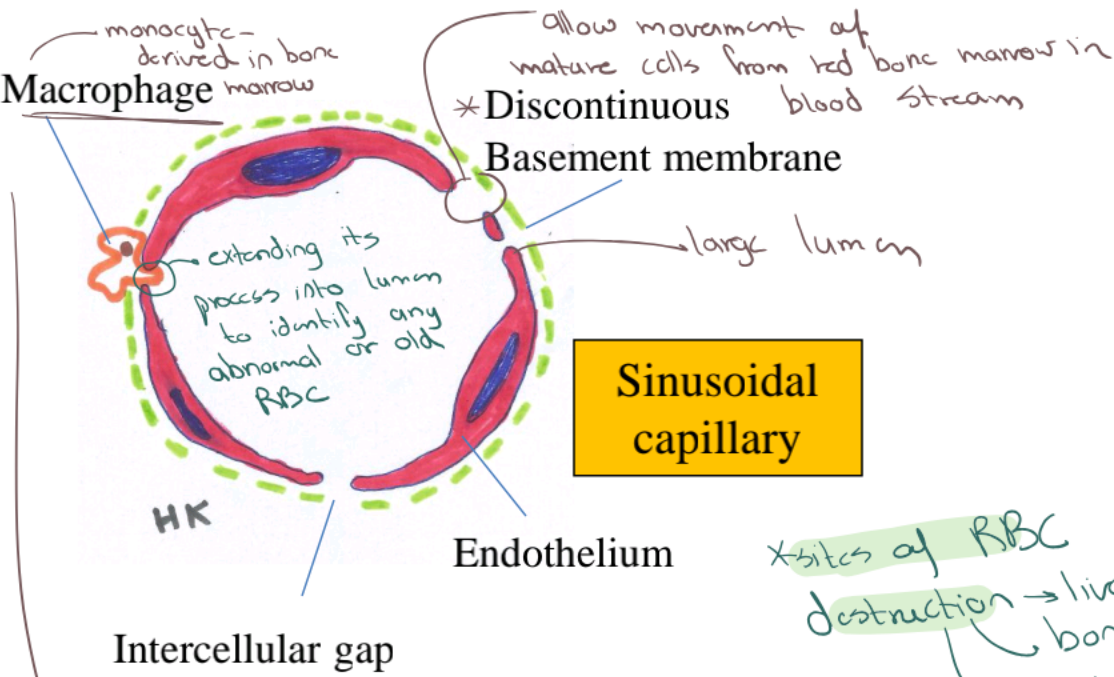
reticular
tissue is
stroma

sinusoidal
capillaries

HPSC
form
pancytopenia
of RBC

few no. of adipocytes
in RBC

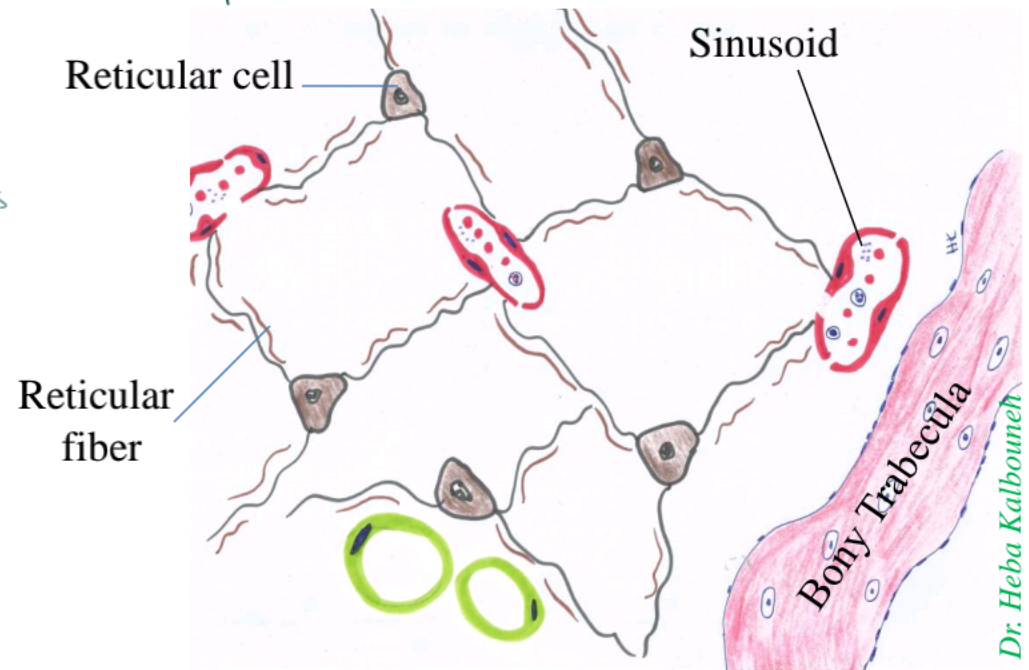
Bony
trabeculum



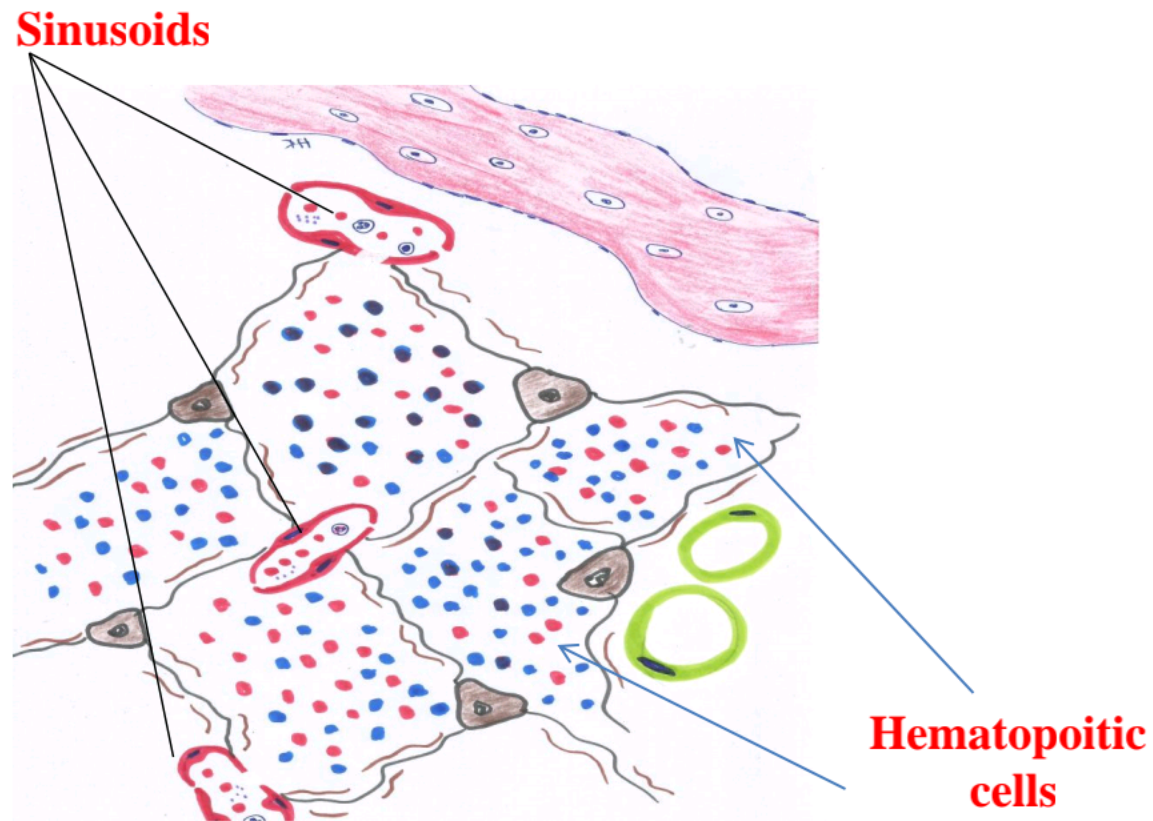
sites of RBC destruction → liver
bone marrow
spleen

resident cells located in tissue surrounding sinusoids - -
- peri sinusoidal CT -
↳ loose CT surrounding all capillaries

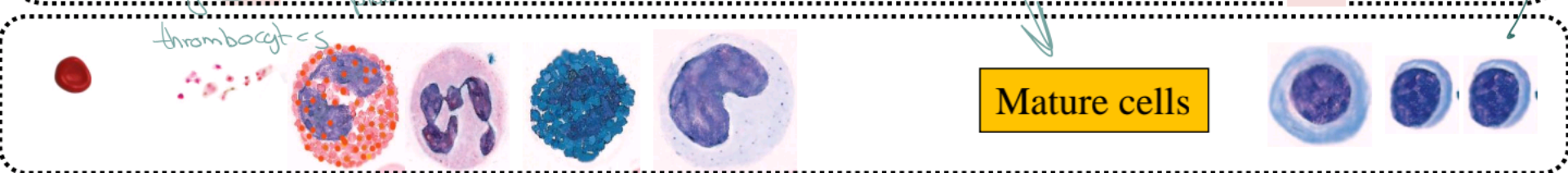
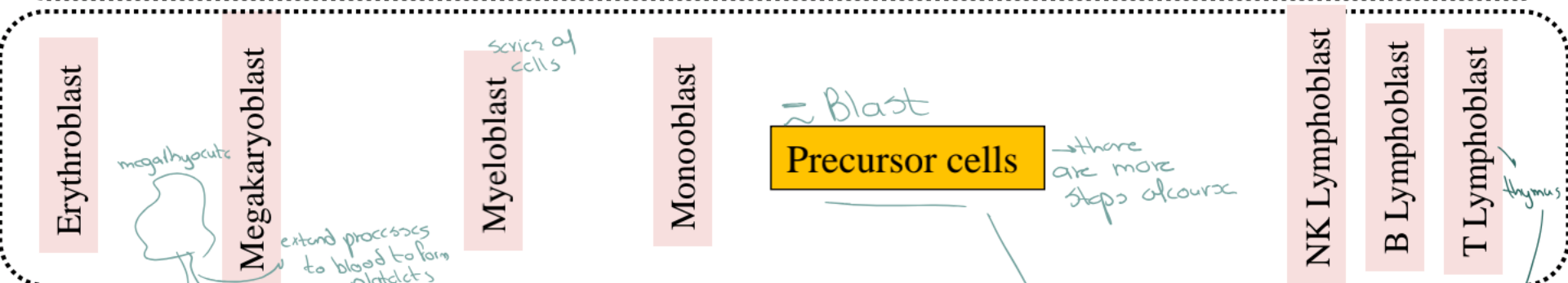
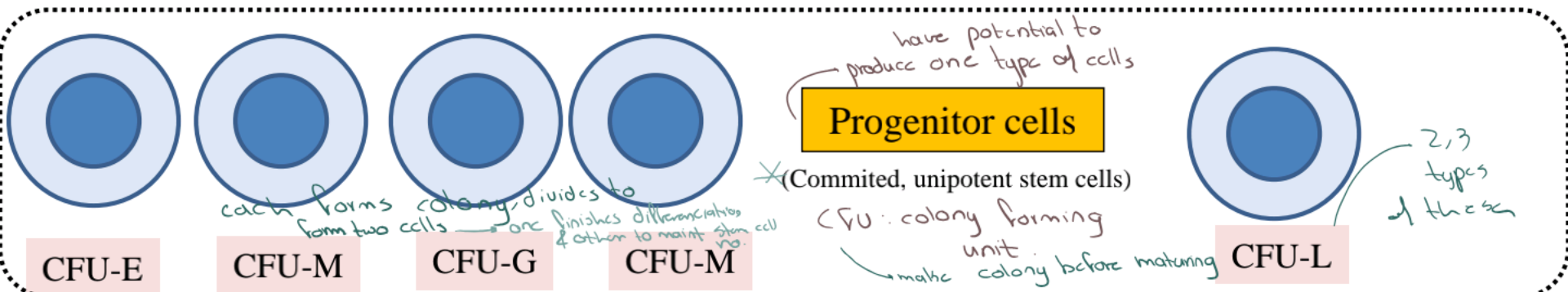
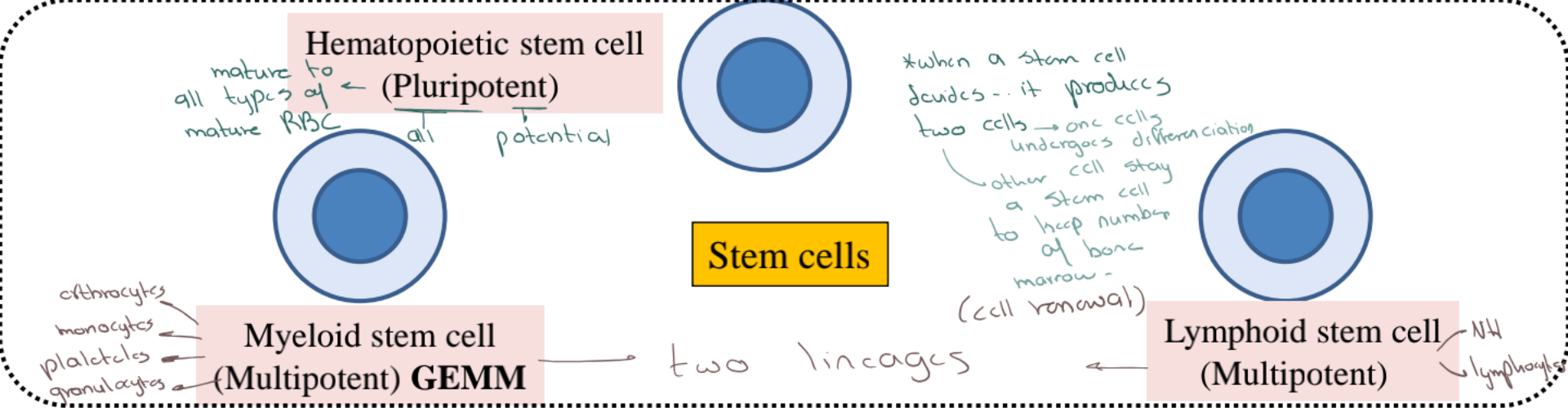
Reticular tissue forming the stroma of the bone marrow



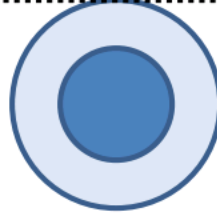
Between the hematopoietic cells run the **sinusoids**, which have discontinuous endothelium, through which newly differentiated blood cells and platelets enter the circulation



Red marrow is also a site where older, defective erythrocytes undergo phagocytosis by macrophages, which then reprocess heme-bound iron for delivery to the differentiating erythrocytes.

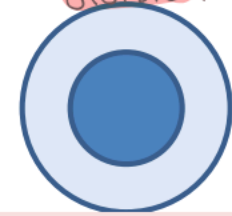


Hematopoietic stem cell
(Pluripotent)



Small pool

*some cells can maintain original number by division others can't

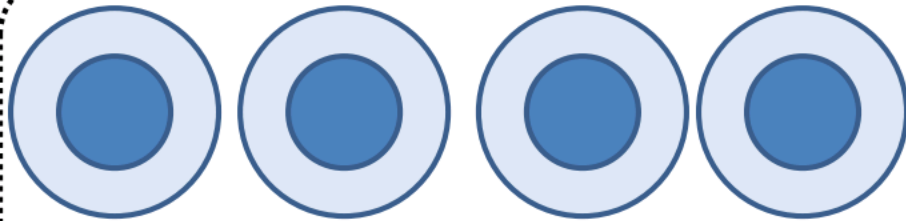


Myeloid stem cell
(Multipotent) **GEMM**

Stem cells

* divide at slow rate → sufficient only to maintain small number in bone marrow

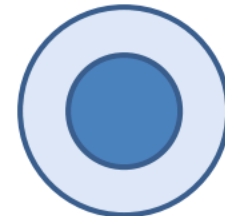
Lymphoid stem cell
(Multipotent)



Progenitor cells

(Committed, unipotent stem cells)

large pool



CFU-E

CFU-M

CFU-G

CFU-M

CFU-L

Erythroblast

Megakaryoblast

Myeloblast

Monooblast

rapid division to maintain large no. of mature cells in peripheral blood

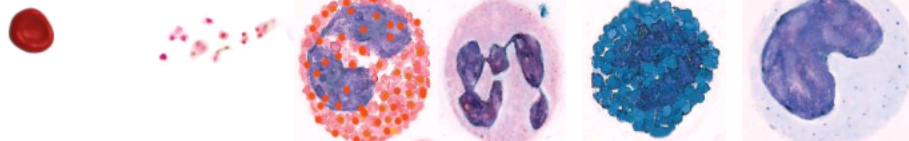
Precursor cells

large pool

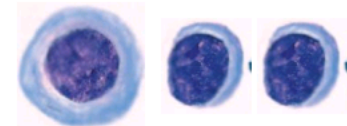
NK Lymphoblast

B Lymphoblast

T Lymphoblast

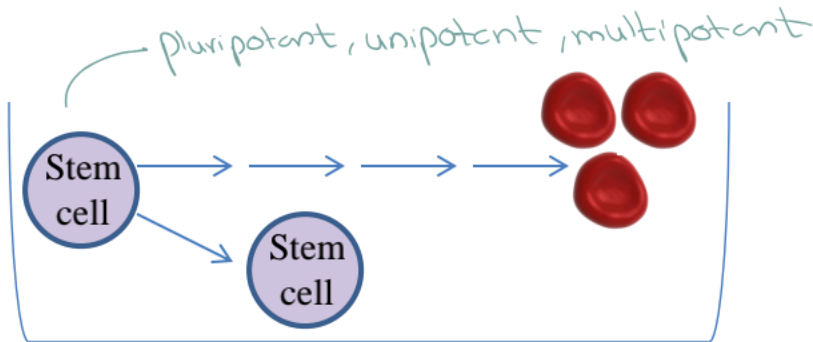


Mature cells



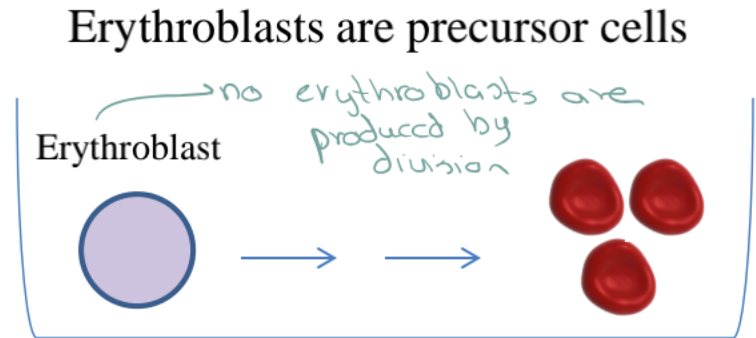
Stem cells are capable of asymmetric division and self-renewal.

Stem cells can maintain the original population



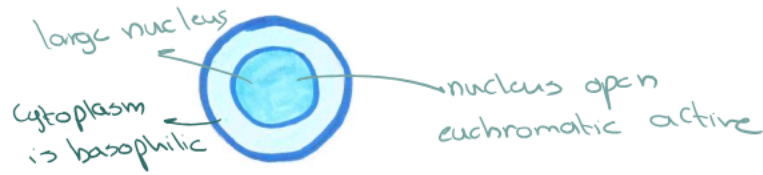
Every time the stem cell multiplies, it will give two cells, one differentiate into mature RBCs and the other cell add to the original population

Precursor cells produce only mature blood cells



All Erythroblasts multiply and differentiate into mature RBCs (erythrocytes) and **no** erythroblasts are left in the end

Hematopoietic pluripotent stem cells



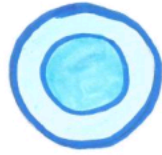
Note:

Stem cells and progenitor cells cannot be morphologically distinguished and resemble large lymphocytes

Myeloid stem cells



Lymphoid stem cells



Rate of cell division:

Slow in Stem cells

Rapid in progenitor and precursor cells

Progenitor cells/ CFUs

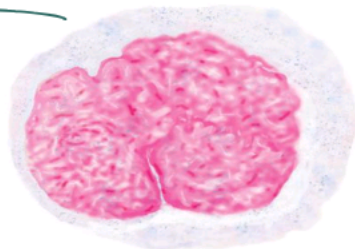
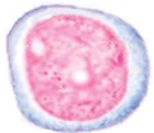


All progenitor cells (CFUs) produce precursor cells (or blasts)

Precursor cells/ Blasts

characteristic for each lineage -

Selected precursors of different blood cells



Precursor cells gradually assume the morphologic characteristics of the mature, functional cell types they will become

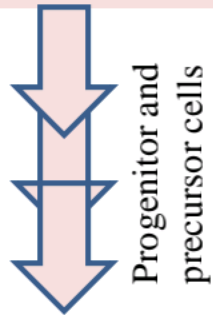
Pluripotent hematopoietic stem cells

All blood cells arise from a single type of stem cell in the bone marrow called pluripotent stem cell

It can produce ALL BLOOD CELL TYPES

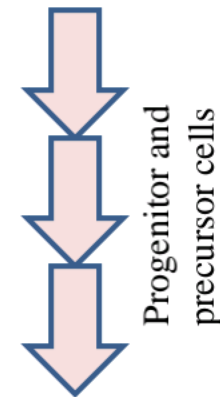
It proliferates and forms two major cell lineages

Myeloid stem cells



Granulocytes
-Neutrophils
-Basophils
-Eosinophils
Erythrocytes
Megakaryocytes
Monocytes

Lymphoid stem cells



Note: pre T-cells (precursor T cells, T lymphoblasts) migrate to the thymus where they proliferate and differentiate.

T lymphocyte
B lymphocyte
Natural killer cells

Pluripotent hematopoietic stem cells

Myeloid stem cells

CFU Erythrocyte
CFU-E

CFU Granulocyte-
Monocyte
CFU-GM

CFU Megakaryocyte
CFU-M

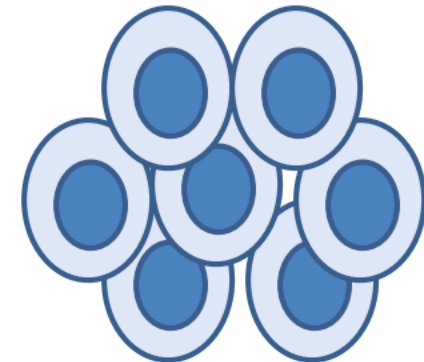
CFU Monocyte
CFU-M

CFU Granulocyte
CFU-G

Lymphoid stem cells

CFU Lymphocyte
CFU-L

The progenitor cells for blood cells are often called **colony-forming units (CFUs)**, because they give rise to colonies of only one cell type when cultured in vitro or injected into a spleen.



Blood Cell Formation (Hematopoiesis)

Throughout childhood and adult life, erythrocytes, granulocytes, monocytes, and platelets continue to form from stem cells located in bone marrow

Important & required

Erythropoiesis: the process which produces erythrocytes

Granulopoiesis: the process which produces granulocytes

Thrombopoiesis: the process which produces thrombocytes

Lymphopoiesis: the process which produces lymphocytes

Monocytopoiesis: the process which produces monocytes

Remember
Lymphopoiesis occurs in the marrow and in the lymphoid organs to which precursor cells migrate from marrow.

Proerythroblast

- nucleated cell
- basophilic cytoplasm
- larger

Basophilic erythroblast

Polychromatophilic erythroblast

Normoblast

Reticulocyte

- smaller
- acidophilic cytoplasm
- anucleated cell

Erythrocyte

* Nuclear maturation

* Cytoplasmic maturation

Erythropoiesis (red cell formation)

synthesis of Hb inside cytoplasm of cell → iron protein AA

✓ Takes about 1 week

✓ Rate is controlled by the hormone erythropoietin (secreted by the kidney cells) and the availability of iron, folic acid, vitamin B12, protein precursors

* size of cell & nucleus ↓ until nucleus disappears.
* becomes acidophilic due to Hb - basic protein -

Stages of differentiation are characterized by:

- 1- Decreasing cell size
- 2- Progressive loss of organelles

Presence of free ribosomes at early stages

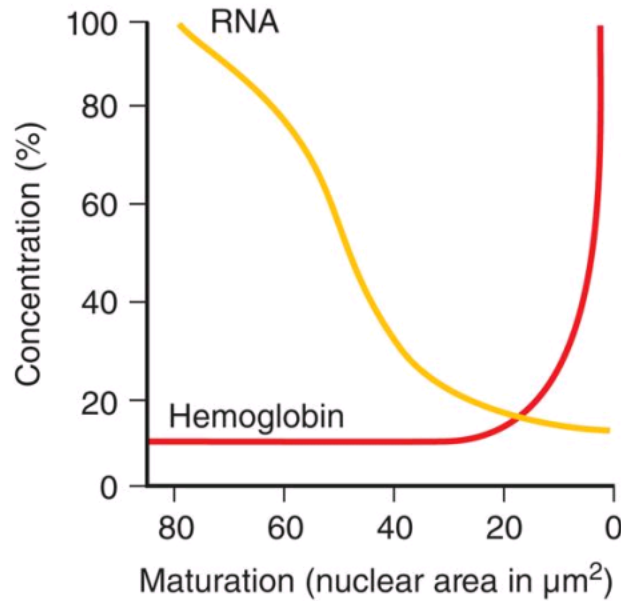
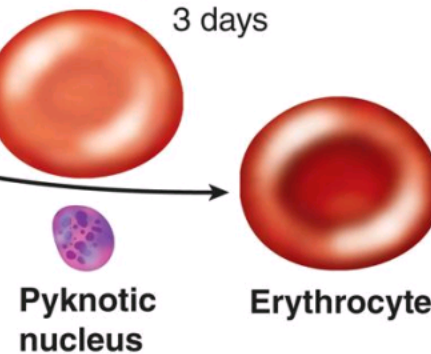
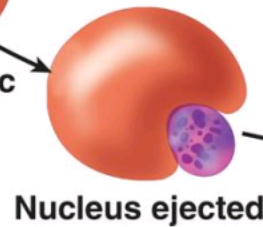
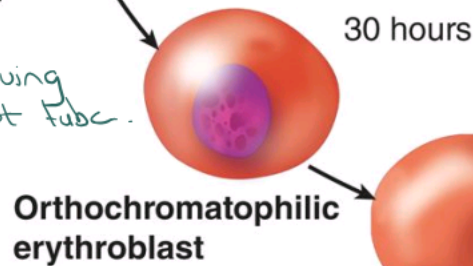
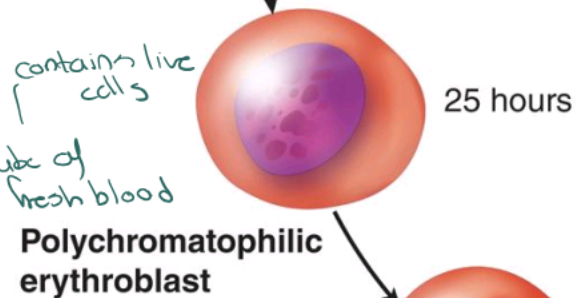
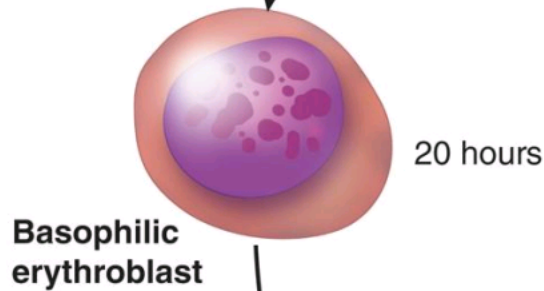
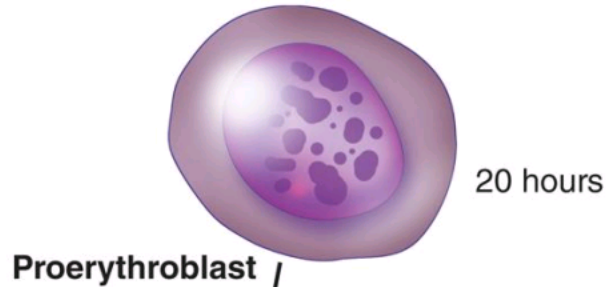


Accounts for the marked cytoplasmic basophilia (**blue**)

- 3- Progressive increase in hemoglobin content



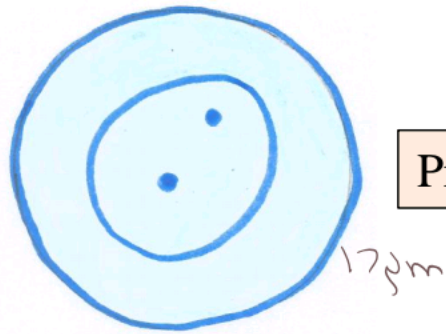
Accounts for increasing eosinophilia (**pink/red**)



** erythropoiesis takes ~1 week
 ↳ given erythropoietin to a patient
 will show improvement after a week*

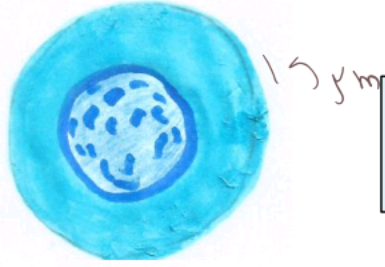
supravital stain to stain living cells outside the body in test tube. by applying supravital dye-

**vital stain - stain living animal by injecting a stain in the blood (e.g. indian ink) & as this dye circulates in blood, it will be encountered by resident macrophages & will be phagocytose it... taking a section of the animal show pigmented macrophages -*



Proerythroblast

- ✓ The first recognizable erythrocyte precursor
- ✓ Largest cell (17um) $\Rightarrow$ each step decreases $\approx 2\mu m$
- ✓ Large pale nucleus with prominent nucleolus
- ✓ Pale basophilic cytoplasm $\hookrightarrow$ active & $\uparrow$ ribosomes



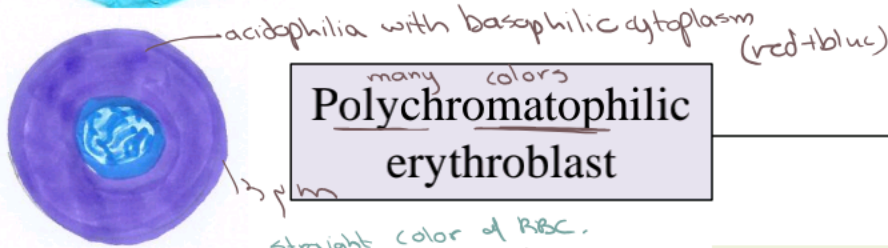
Basophilic erythroblast

- ✓ The cell becomes smaller (15um)
- ✓ Nucleus: smaller and darker
- ✓ Deeply basophilic cytoplasm (high in ribosomes)

maximum no. of ribosomes

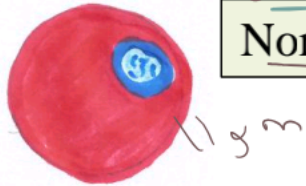
as going from here: $\uparrow$ Hb & $\downarrow$ ribosomes

$\hookrightarrow$ $\uparrow$ ribosomes $\rightarrow$ start forming Hb



Polychromatophilic erythroblast

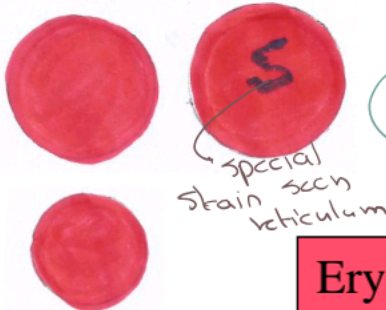
- ✓ The cell becomes smaller (13um)
- ✓ Nucleus: smaller and darker
- ✓ Cytoplasm becomes violet
- ✓ Takes basic (ribosomes) and acidic stains (Hb)



Normoblast

- ✓ The cell becomes smaller (11um)
- ✓ Nucleus: smaller, darker and eccentric to be expelled outside
- ✓ Cytoplasm is acidophilic (Hb)

The nucleus is extruded at this stage



Reticulocyte

- ✓ Immature erythrocyte but slightly larger (9um)
- ✓ No nucleus
- ✓ Cytoplasm is acidophilic (Hb) but contains remnants of ribosomes forming reticulum
- ✓ Can be stained by supravital stains (brilliant cresyl blue)

Erythrocyte

straight color of RBC.
~ orthochromatophilic

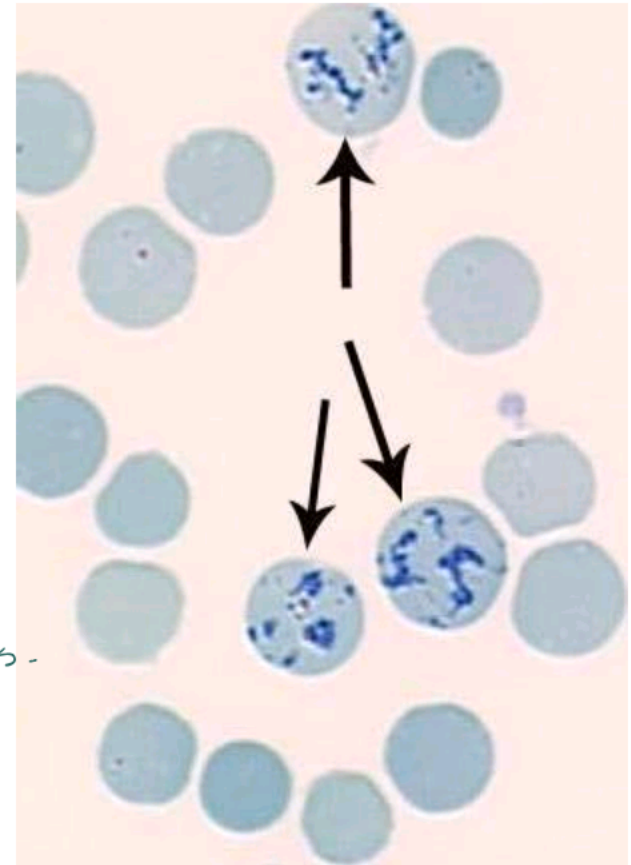
normal color of erythrocyte - was named acidophilic erythroblast -

special stain seen reticulum

Reticulocytes

- Are immature red blood cells (last stage)
- The cell has extruded its nucleus, but is still capable of producing hemoglobin.* **WHY??**
- Supravital dye: precipitation of reticulum in the cytoplasm (brilliant cresyl blue)
- Normally, only about 1% of all red blood cells in the bloodstream are reticulocytes
- They circulate for about 1-2 days before developing into mature red blood cells
- An increase in reticulocytes ---- blood loss (hemorrhage) → overactivate bone marrow →

Very important
CLINICALLY



Reticulocyte

Mature Erythrocyte

↑ immature product in peripheral blood -

most likely
blood loss -

*if you take
a film & notice
↑ reticulocyte of peripheral
blood



Granulopoiesis (Neutrophils, Eosinophils and Basophils formation)

✓ Takes about 2 weeks

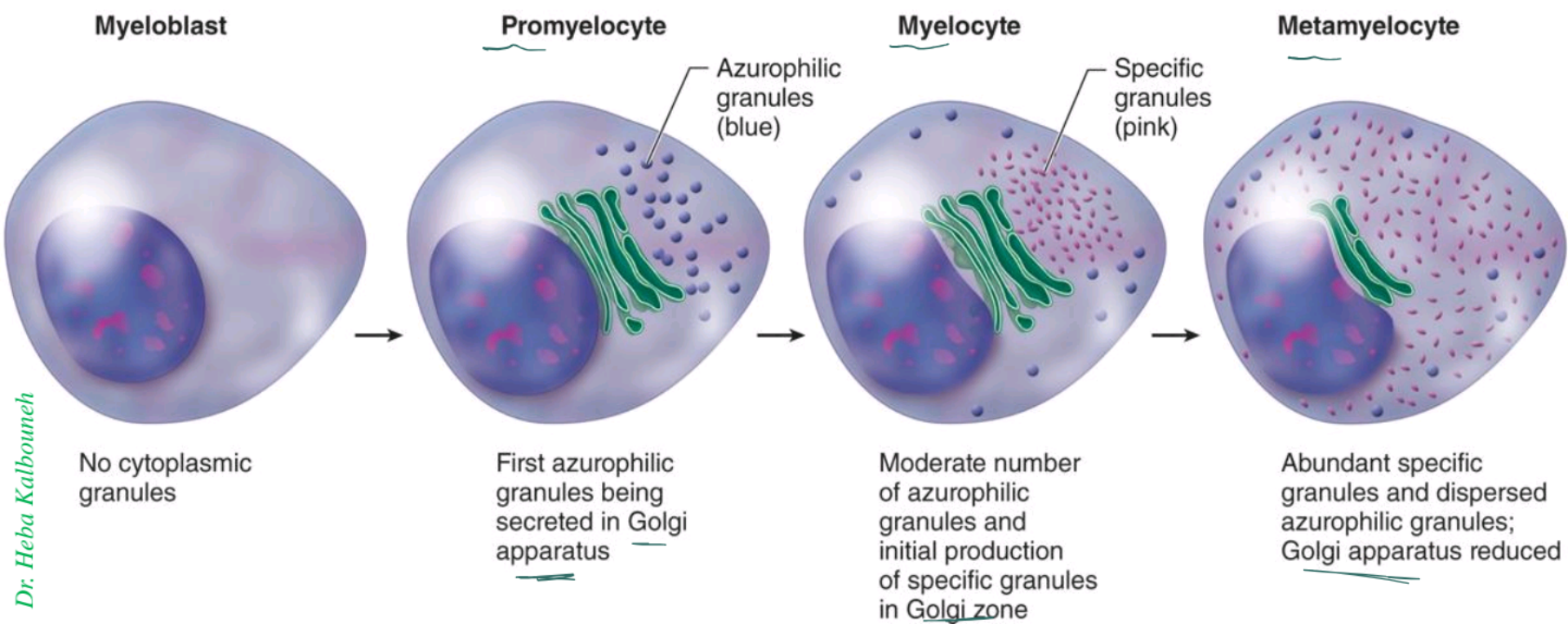
Stages of differentiation are characterized by:

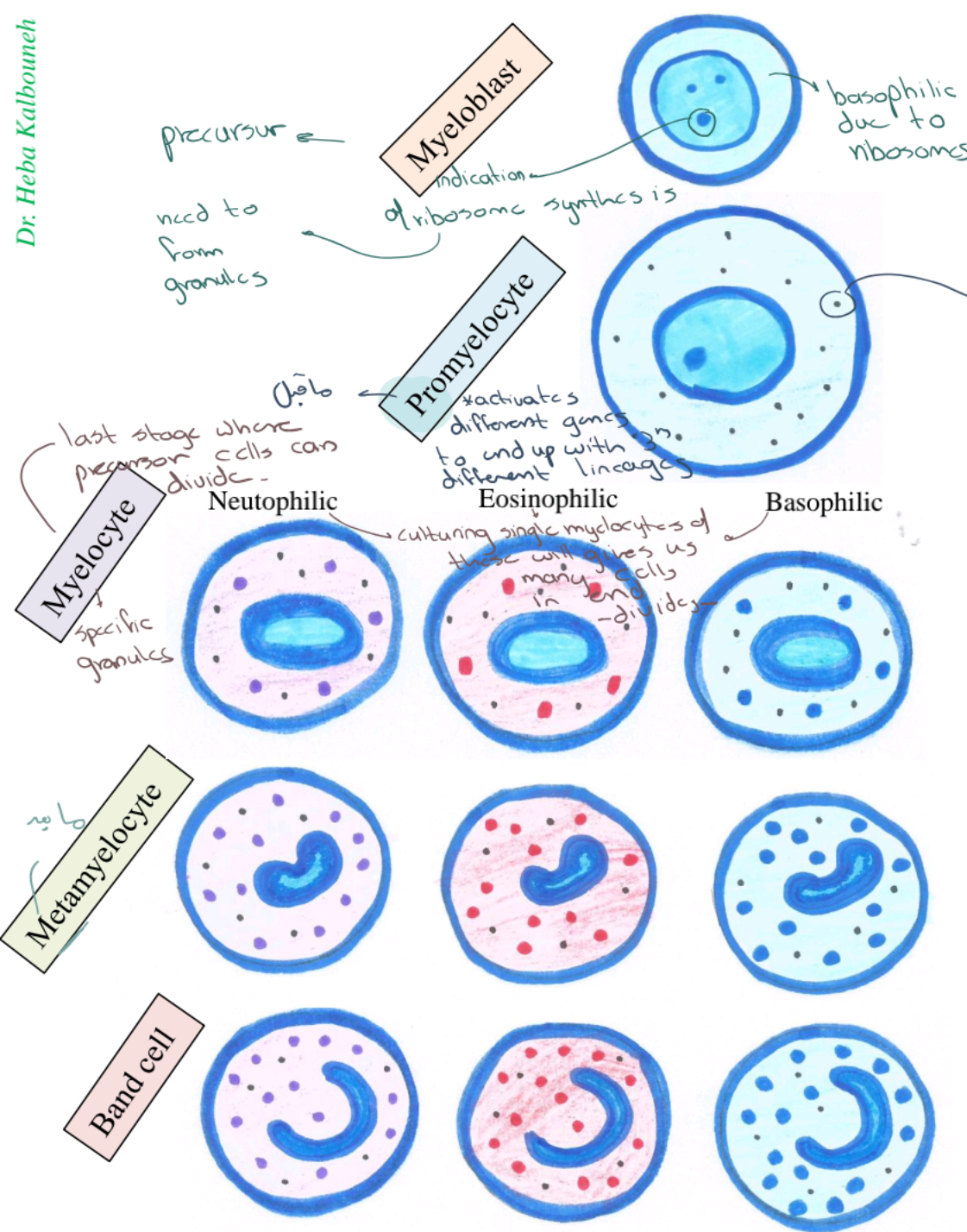
1- Cytoplasmic changes dominated by synthesis of ^{primary} azurophilic granules and ^{secondary} specific granules.
same in all



First, formation of the azurophilic granules (similar in all three types of granulocytes)
Second, formation of the specific granules (differ in each of the three types of granulocytes)
**start with euchromatic open nucleus.*

2- Condensation, indentation and segmentation of the nucleus *⇒ nuclear changes*





Myeloblast

prominent nucleolus & large active nucleus euchromatic.

- ✓ The first recognizable precursor

Promyelocyte

- ✓ The largest (20um)
 - ✓ Azurophilic granules start to appear
- primary granules

Myelocyte

- ✓ 3 types
 - ✓ The cell becomes smaller
 - ✓ The nucleus becomes smaller and darker
 - ✓ Specific granules start to appear
- nuclear condensation = ↑ heterochromatin ↓ euchromatin

Metamyelocyte

- ✓ 3 types
 - ✓ Cannot divide
 - ✓ Undergoes metamorphosis
 - ✓ Nucleus becomes indented (kidney shaped)
 - ✓ Specific granules increase in number
- all cells before can divide ✓
- only mature from now on.
- change in morphology only without mitosis

Band cell (stab cell)

- ✓ 3 types
 - ✓ Nucleus becomes curved rod in shape
- more indented → band nucleus.

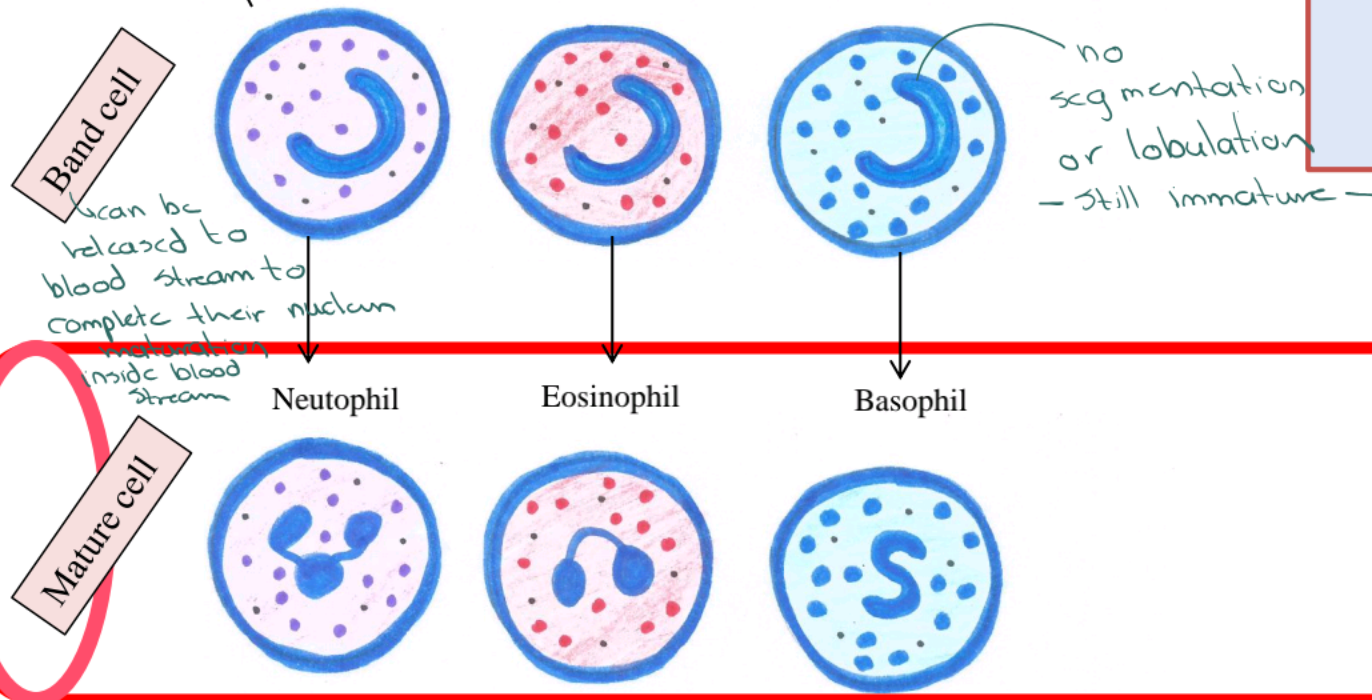
Neutrophilic band cells (important CLINICALLY)

Their percentage does not exceed 5% in peripheral blood



The appearance of large numbers of immature neutrophils (band cells) in the blood, sometimes called a “shift to the left,” is clinically significant, usually indicating a **bacterial infection**.

This means that the bone marrow has been signaled to release more neutrophils and increase production of neutrophils



*Band cell is **almost** a mature neutrophil, just doesn't have a segmented nucleus yet

normal to see in peripheral blood & inside blood



*exercise: marginating → circulating
- neutrophilia

*administration of: neutrophils storage → circulating
epinephrine

*cortisol: ↑ granulopoiesis
& marginating → circulating

Bone marrow pool

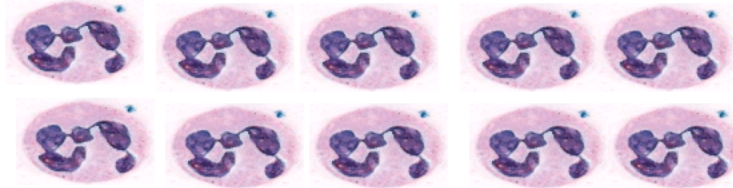
*neutrophilia: increase in number of neutrophils inside peripheral blood... doesn't always mean ↑ granulopoiesis is happening & ↑ activation of precursor cells... Can be due to movement of mature

Myeloblast
Promyelocyte
Myelocyte
Metamyelocyte
Band cell
Neutrophil → mature

dividing
& maturing
cells

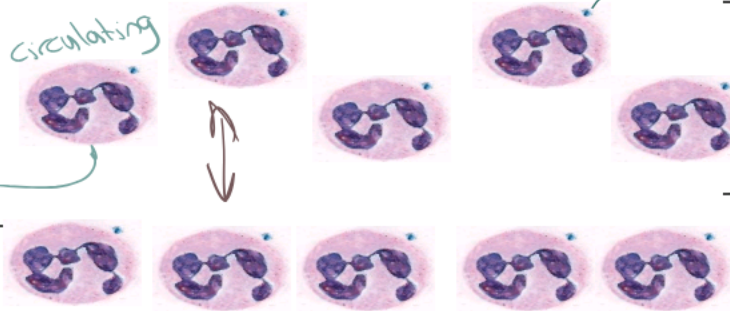
⇒ granulopoietic pool.

waiting for release ⇒ storage pool



if no infection present → live few hours then die by apoptosis then phagocytosed by macrophages in spleen, liver & bone marrow

neutrophils from storage pool or marginating pool to circulating pool



during exercise they move to

neutrophils circulate in blood stream a couple of hours → enter infection sites & live few days then die... phagocytosed by macrophages within GT.

Circulating pool

Marginating pool

loosely attached to endothelium ⇒ located inside blood but not truly circulating

⇒ can stay like this without entering connective tissue - continuous movement between marginating pool & circulating pool.

Developing and mature neutrophils exist in **four functionally and anatomically defined compartments:**

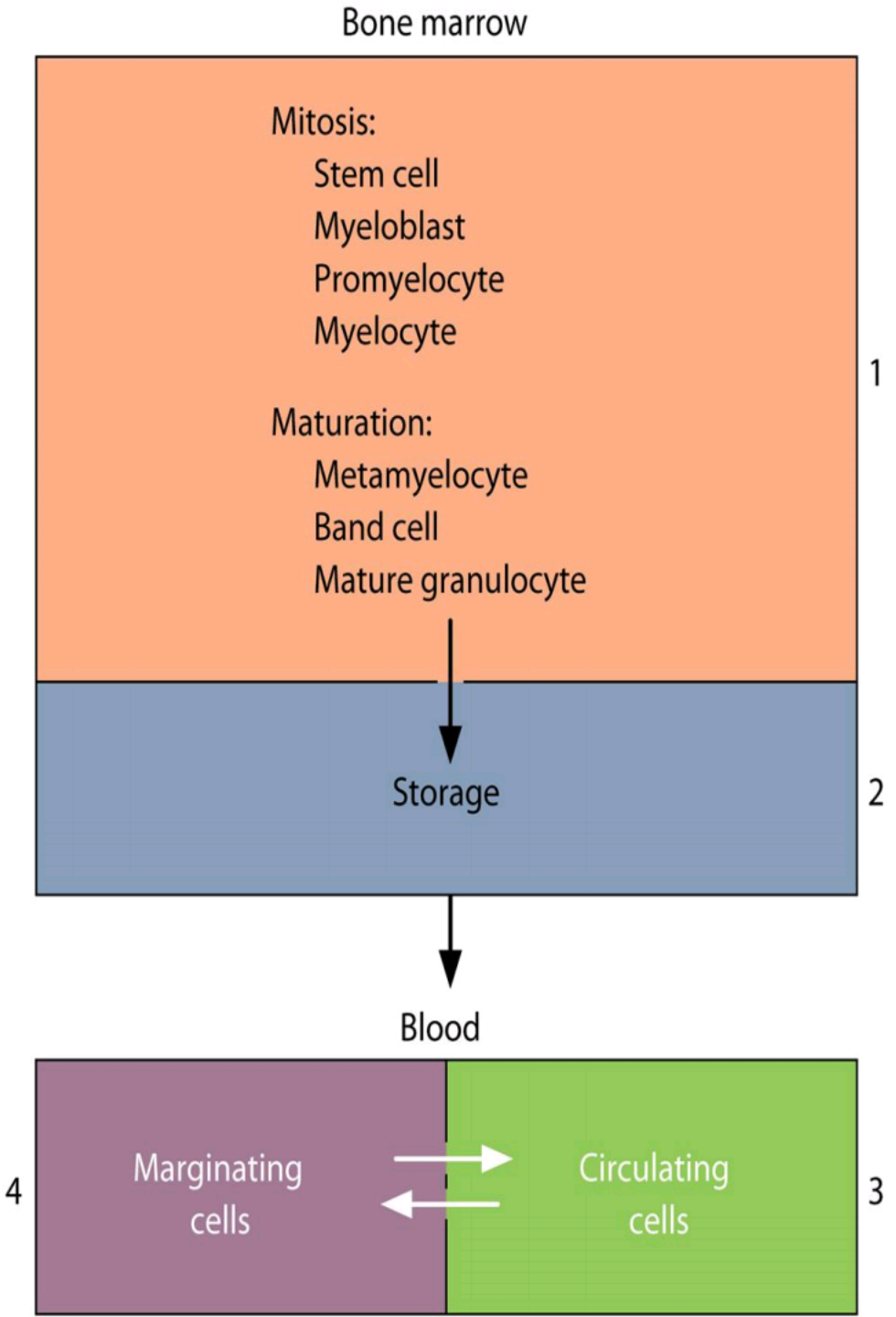
- (1) The granulopoietic compartment in active marrow
- (2) Storage as mature cells in marrow until release
- (3) The circulating population
- (4) A population undergoing margination



Margination is a process in which neutrophils adhere loosely and accumulate transiently along the endothelial surface in venules and small veins.

Note: Margination of neutrophils in some organs can persist for several hours and is not always followed by the cells' emigration from the microvasculature.

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At sites of injury or infection, neutrophils and other granulocytes enter the connective tissues by migrating through intercellular junctions between endothelial cells of postcapillary venules in diapedesis.



Inflamed connective tissues thus form a fifth terminal compartment for neutrophils, where the cells reside for a few days and then die by apoptosis, regardless of whether they have performed their major function of bacterial phagocytosis.

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Changes in the number of neutrophils in the blood must be evaluated by taking all their compartments into consideration.

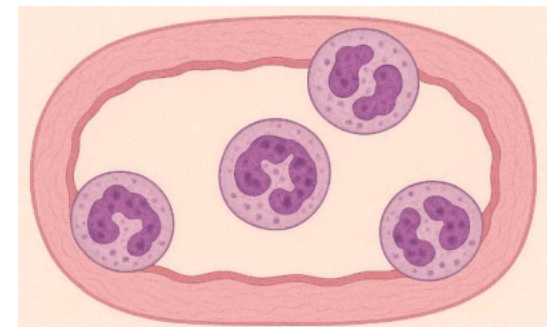
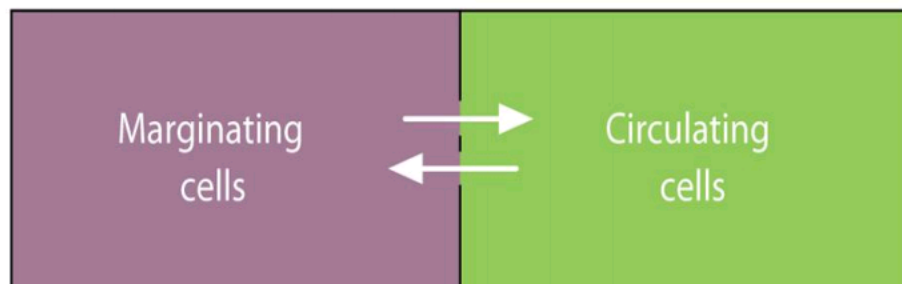


Thus, neutrophilia (an increase in the number of circulating neutrophils) does not necessarily imply an increase in granulopoiesis.



Intense muscular activity or the administration of epinephrine can cause neutrophils in the marginating compartment to move into the circulating compartment, producing neutrophilia even though granulopoiesis has not increased. However, glucocorticoids (adrenal hormones) such as cortisone increase the mitotic activity of neutrophil precursors and this also increases the blood count of neutrophils.

Blood



How many RBCs are in 1 ul of peripheral blood?

5 million/ul

How many WBCs are in 1 ul of peripheral blood?

4500-11000/ul

But in the bone marrow (myeloid tissue)!!!

Myeloid: Erythroid

3:1

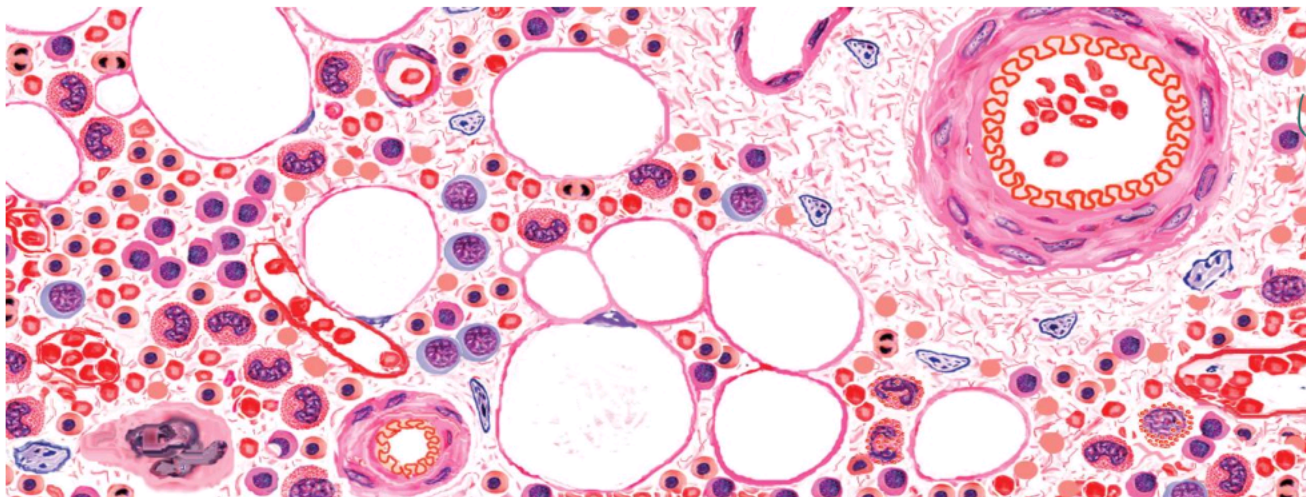
Remember the life span!!!!

even though
in blood
4.5-5.5 RBC /mm³
400-1100 WBC /mm³

other name

most cells are precursors for granulocytes → why they are named myelocytes

RBC live 120 days while granulocytes (few hours - days) - need ↑ precursors

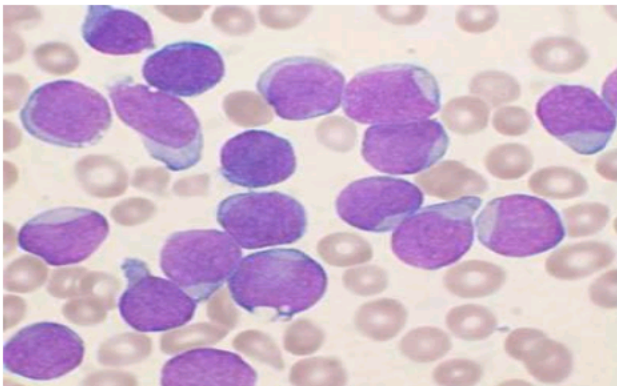
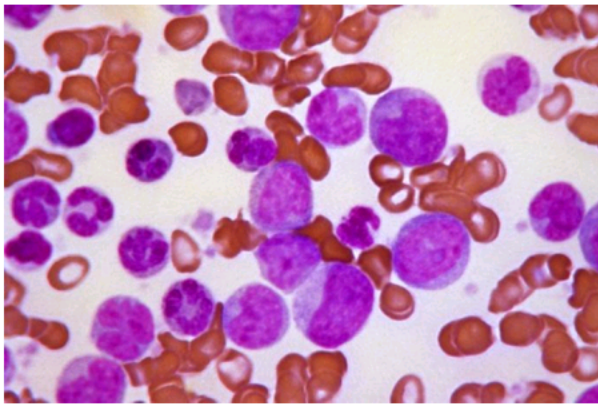


White blood cell abnormalities

Increased numbers of white cells appear in the peripheral blood in a variety of disorders and provide a useful clue to the underlying disease.

A considerable and sustained increase of circulating **neutrophils** in **bacterial infection**

An increase of circulating **eosinophils** in **parasitic infection and some allergies**



***Leukemia** is a malignant proliferation of white cell precursors in the bone marrow *neoplastic changes*



Vast number of white cells and their precursors (many of which spill over into the blood)
Leukemia is classified according to the cell line involved (granulocytic, monocytic, lymphocytic)

Stem cells Progenitor cells Precursor cells

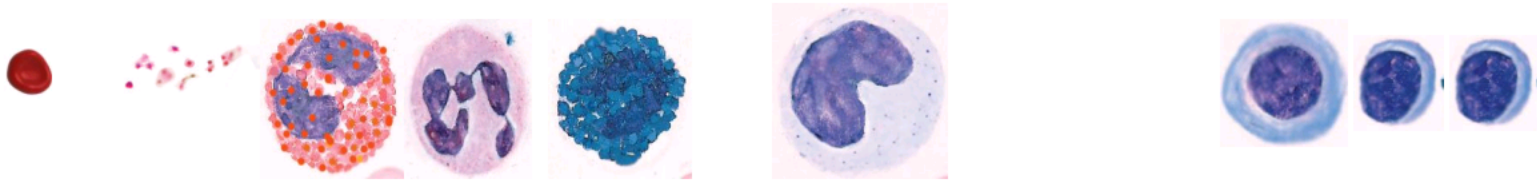
Bone marrow

not seen
in
blood
except for band
cells & reticulocytes
at a certain %

these cells can
be destroyed by
radiation/chemotherapy/
autoimmune diseases
which causes hypoplasia.
inside bone marrow
(or even aplastic)

suppression
in activity of
these cells.
↳ can't divide to
maintain number of cells

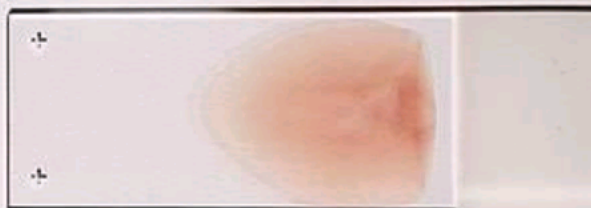
Peripheral blood



Blood film/ smear

if you
observe reduction in all
types of cells or
see abnormal precursor
cells in peripheral blood

should take something called
bone aspirate or bone
biopsy -

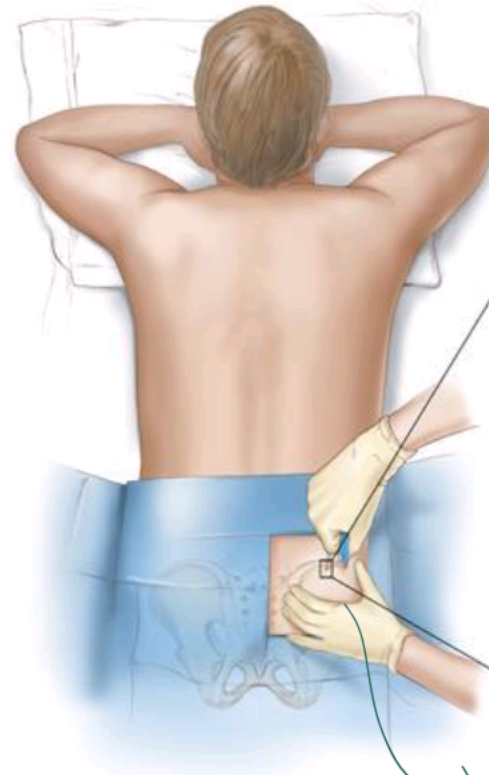


Bone marrow Aspiration or biopsy

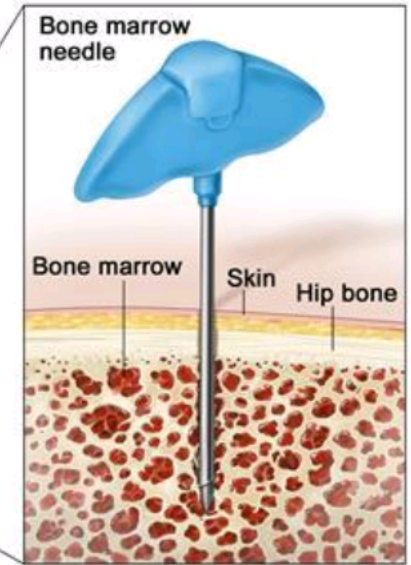
Needed to diagnose disorders like aplastic anemia or leukemia

* condition caused by hypoplastic bone marrow

* anemia here is misnomer; should be called pancytopenia due to reduction in all types of blood cells not only RBCs.



Bone Marrow Aspiration and Biopsy



iliac crest or sternum

glass slide & stain it

Bone marrow transplantation

In bone marrow diseases like leukemia, hematopoietic stem cells taken from a donor are infused into the same or another person

will circulate inside blood until they settle down inside bone marrow.

↳ able to do that due to stroma of bone marrow → reticular cells have specific adhesions that act as homing-in receptor

Thrombopoiesis

formation of platelets

Hematopoietic pluripotent stem cell

Myeloid stem cells

Colony forming unit- megakaryocyte

Megakaryoblast

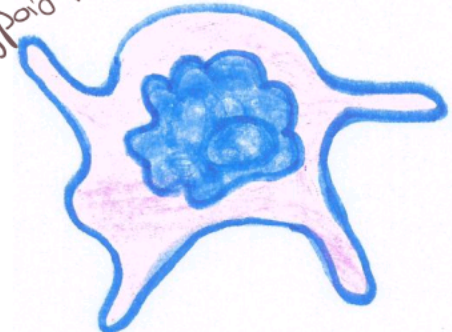
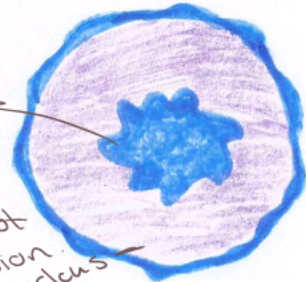
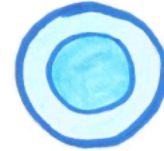
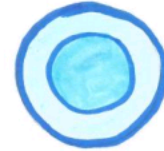
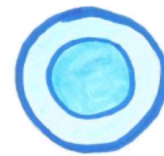
Promegakaryocyte

Megakaryocyte

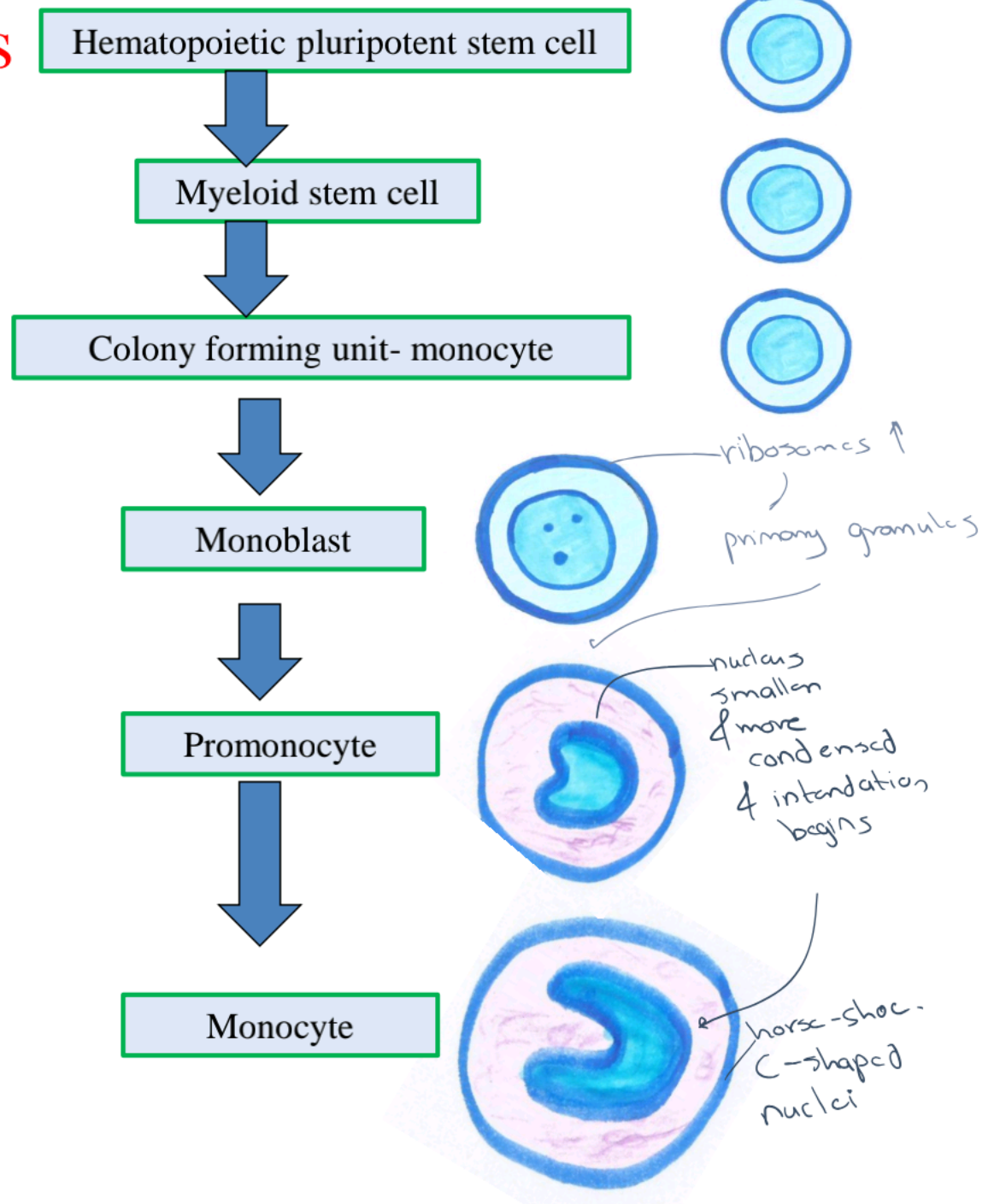
earliest
precursor
identified
here.

large
nucleus
here. -
due nucleus
replicating alot
without division.
- polyploid nucleus

extends processes
in blood stream
& tips break
down in blood
stream forming
platelets



Monocytopoiesis



Lymphopoiesis

Hematopoietic pluripotent stem cell



Lymphoid stem cells



2 / 3
types of
these.

Lymphocyte colony forming cell



Lymphoblast

Thymus



T Lymphocyte

Directly into blood

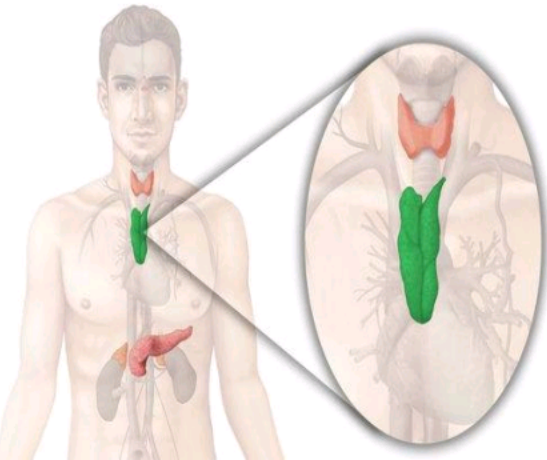
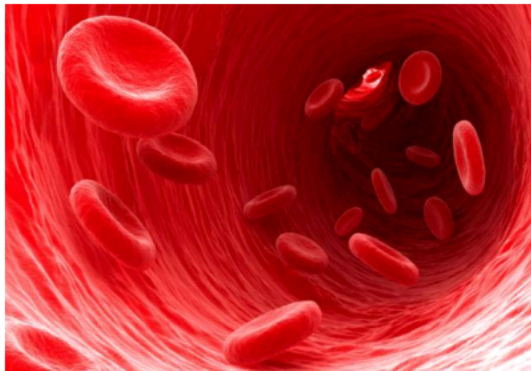


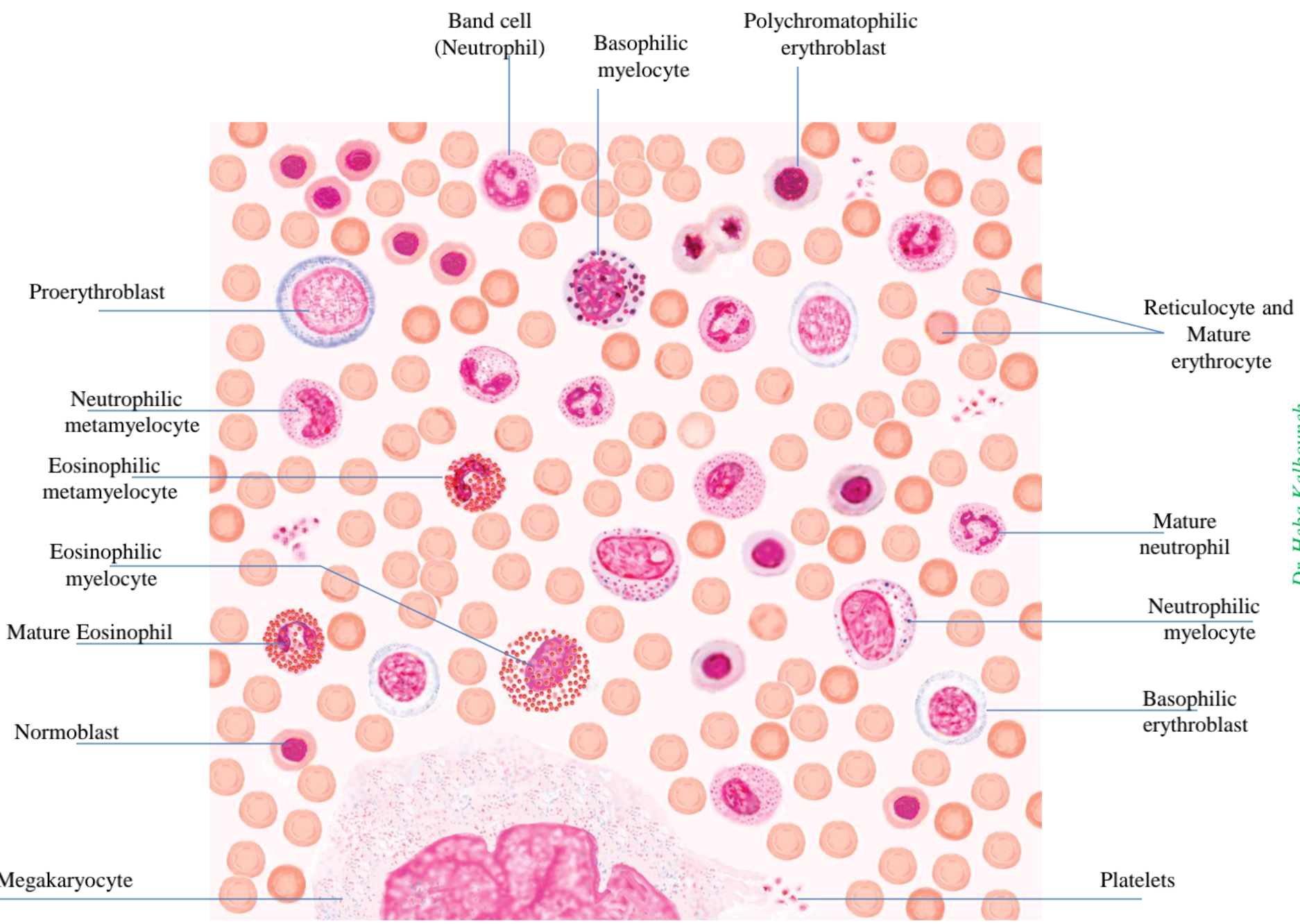
Natural killer lymphocyte

BM



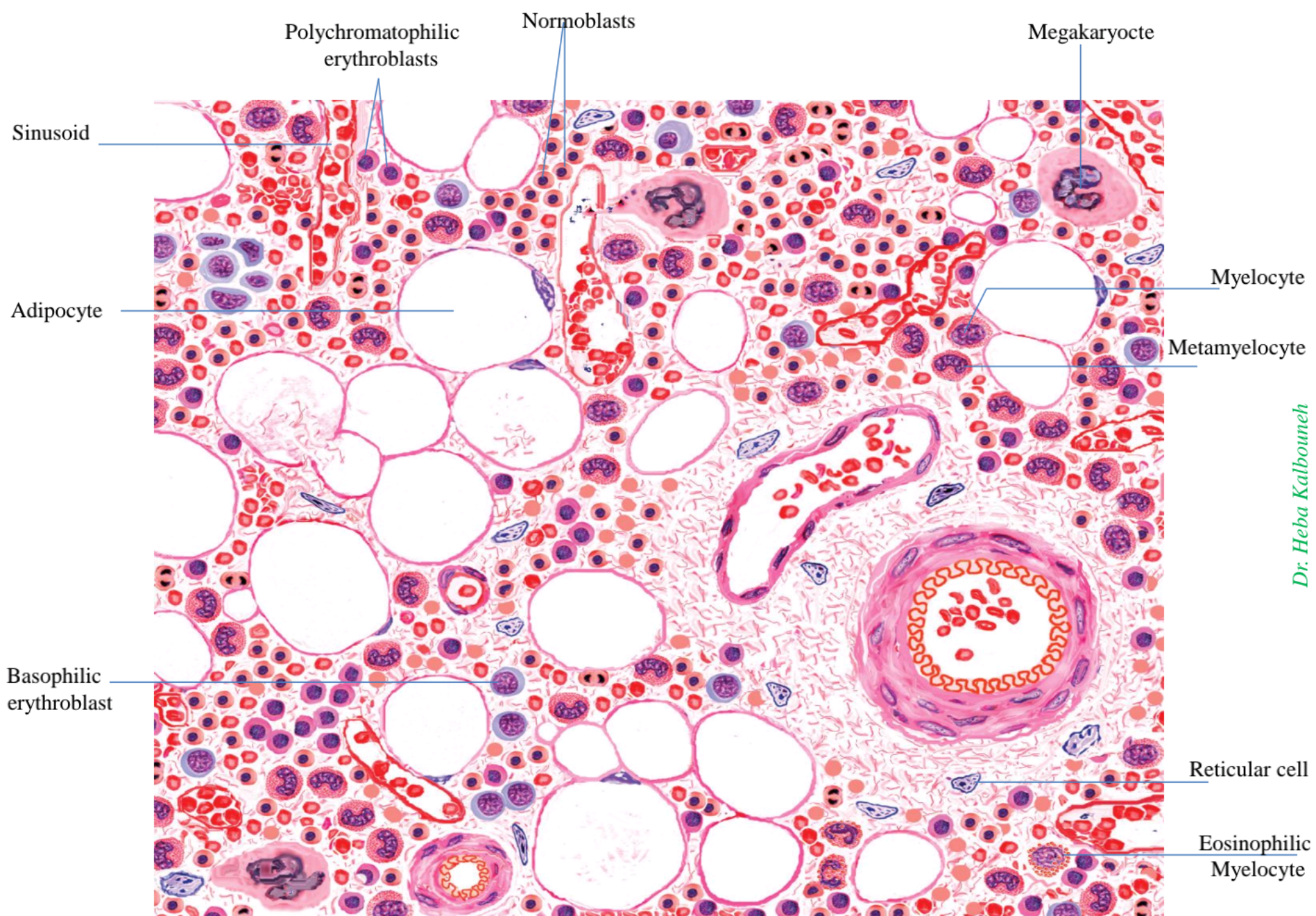
B Lymphocyte





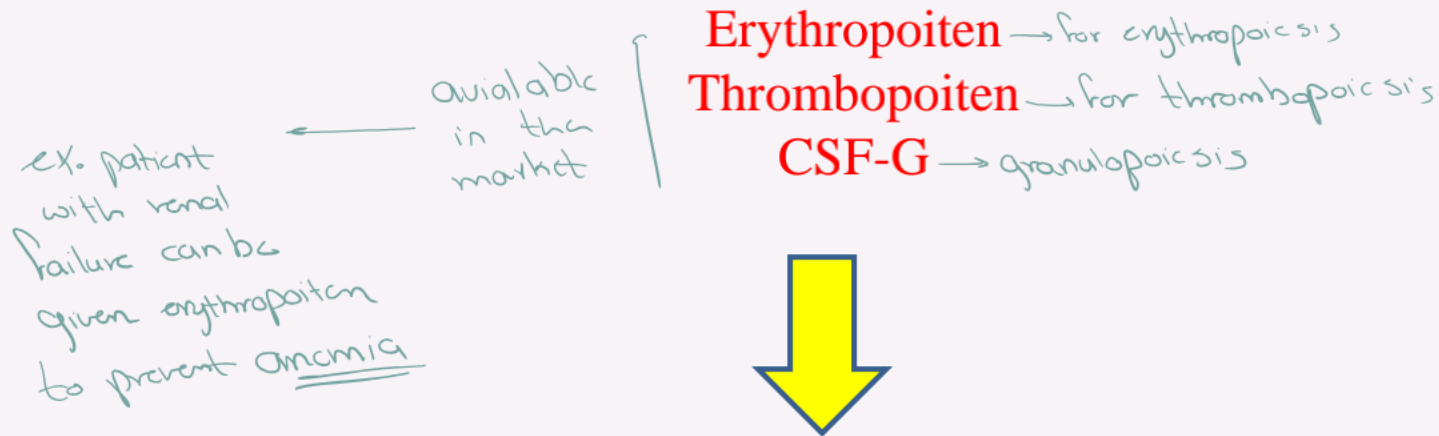
Bone marrow (Giemsa stain)

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Bone marrow (H&E)

Hemopoietic growth factors (colony-stimulating factors (CSF) or cytokines) are glycoproteins that stimulate proliferation of progenitor and precursor cells and promote cell differentiation and maturation within specific lineages.



Cloning of the genes for several important hematopoietic growth factors has significantly advanced study of blood formation and permitted the production of clinically useful factors for patients with hemopoietic disorders.

In which of the following cells involved in erythropoiesis does hemoglobin synthesis begin?

- a. Orthochromatic erythroblast
- b. Polychromatophilic erythroblast
- c. Reticulocyte
- d. Basophilic erythroblast
- e. Proerythroblast

check
answer
from Dr. 

Which of the following can be used to describe megakaryocytes?

- a. Multinucleated
- b. Formed by fusion of haploid cells
- c. Precursors to bone marrow macrophages
- d. A minor but normal formed element found in the circulation
- e. Possess dynamic cell projections from which one type of formed element is released

Which cytoplasmic components are the main constituents of the dark precipitate that forms in reticulocytes upon staining with the dye cresyl blue?

- a. Golgi complexes
- b. Hemoglobin
- c. Nucleoli
- d. Nuclear fragments
- e. Polyribosomes

Which process occurs during granulopoiesis but not during erythropoiesis?

- a. Cells lose their capacity for mitosis
- b. Euchromatin content increases
- c. Nucleus becomes increasingly lobulated
- d. Overall cell diameter decreases
- e. Overall nuclear diameter decreases

What fate often awaits granulocytes that have entered the marginating compartment?

- a. Undergo mitosis
- b. Crossing the wall of a venule to enter connective tissue
- c. Cannot reenter the circulation
- d. Differentiate into functional macrophages
- e. Begin to release platelets

What is the earliest stage at which specific granulocyte types can be distinguished from one another?

- a. Myelocyte
- b. Band form
- c. Reticulocyte
- d. Metamyelocyte
- e. Promyelocyte

Which cell type is capable of further mitosis after leaving the hemopoietic organ in which it is formed?

- a. Basophil
- b. Eosinophil
- c. Reticulocyte
- d. Lymphocyte
- e. Neutrophil



Shortly after her birth a baby is diagnosed with a mutation in the erythropoietin receptor gene which leads to familial erythrocytosis (familial polycythemia). During the seventh to ninth months of fetal development, the primary effect on her red blood cell production was in which of the following?

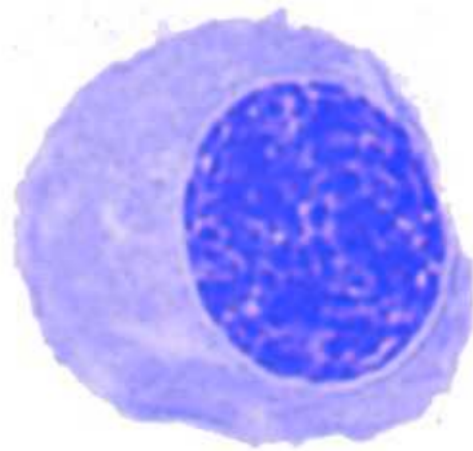
- a. Liver
- b. Yolk sac
- c. Spleen
- d. Thymus
- e. Bone marrow

A 54-year-old man presents with recurrent breathlessness and chronic fatigue. After routine tests followed by a bone marrow biopsy he is diagnosed with lymphocytic leukemia. Chemotherapy is administered to remove the cancerous cells, which also destroys the precursor cells of erythrocytes. To reestablish the erythrocytic lineage, which of the following cells should be transplanted?

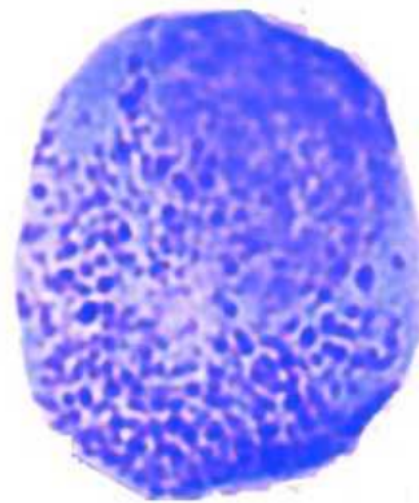
- a. Reticulocytes
- b. Orthochromatophilic erythroblasts
- c. Megakaryoblasts
- d. Basophilic erythroblasts
- e. Metamyelocytes

A smear of blood from a 70-year-old leukemia patient reveals a larger than normal population of cells that have large, round nuclei with 1 or 2 nucleoli. The cytoplasm of these cells shows azurophilic granules. Which of the following forms of leukemia would you suspect?

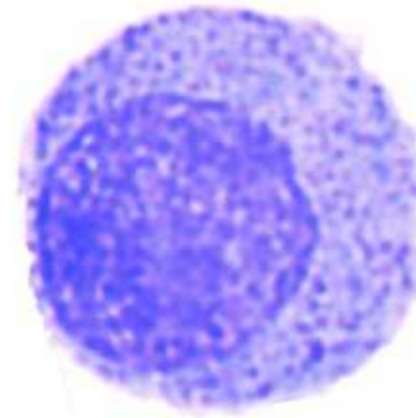
- a. Promyelocytic leukemia
- b. Basophilic leukemia
- c. Lymphoblastic leukemia
- d. Stem cell leukemia
- e. Eosinophilic leukemia



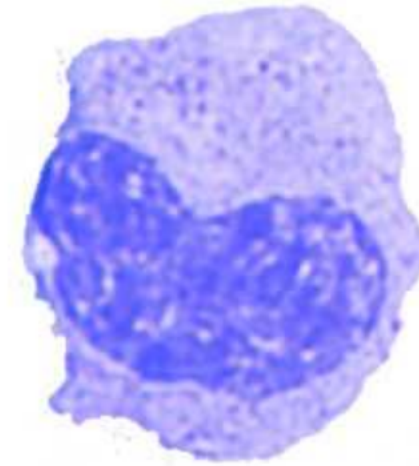
Myeloblast



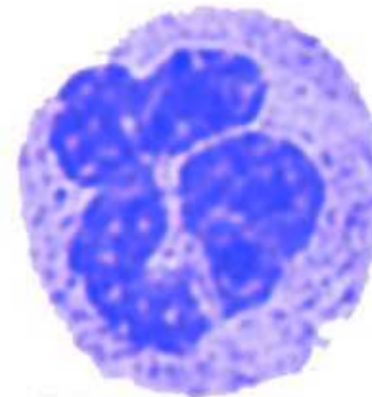
Promyelocyte



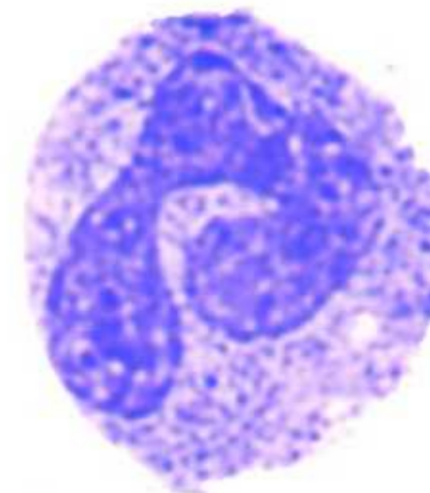
Myelocyte



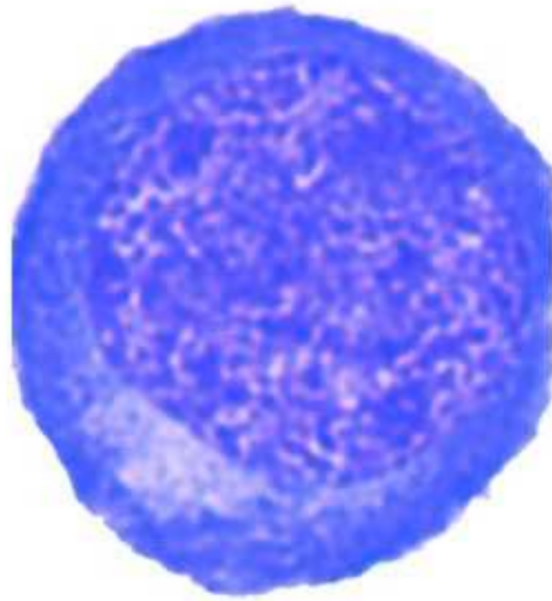
Metamyelocyte



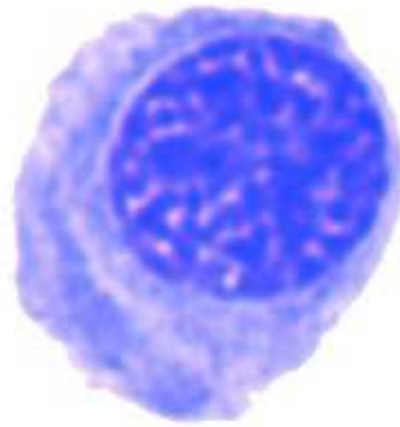
Neutrophil



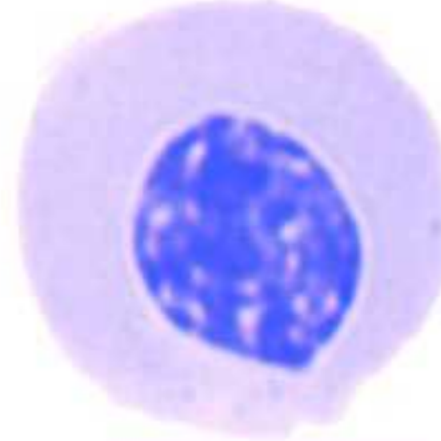
Band cell



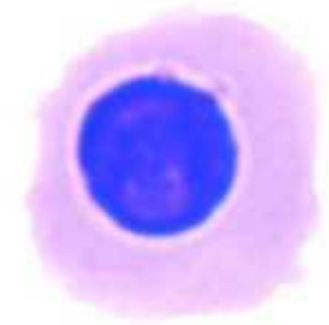
Proerythroblast



Basophilic
erythroblast



Polychromatic
erythroblast



Orthochromatic
erythroblast



Erythrocyte



Reticulocyte