Chapter 32:

Red Blood Cells, Anemia, and Polycythemia

Function of Red Blood Cells

Transport of Hemoglobin

Transport of Carbon Dioxide and oxygen

Acid-base buffer

Definitions

Hematocrit: % volume of blood that is red cells

45 % cells male

40 % cells female

Hemoglobin:

34 g /100 ml red cells

16 g /100 ml blood male

14 g /100 ml blood female

Oxygen carrying capacity:

gm Hg/100 ml blood * 1.34 ml O_2/gm Hb

~21 ml O_2/ 100 ml blood for men

~19 ml O_2/ 100 ml blood for women

Normal Values

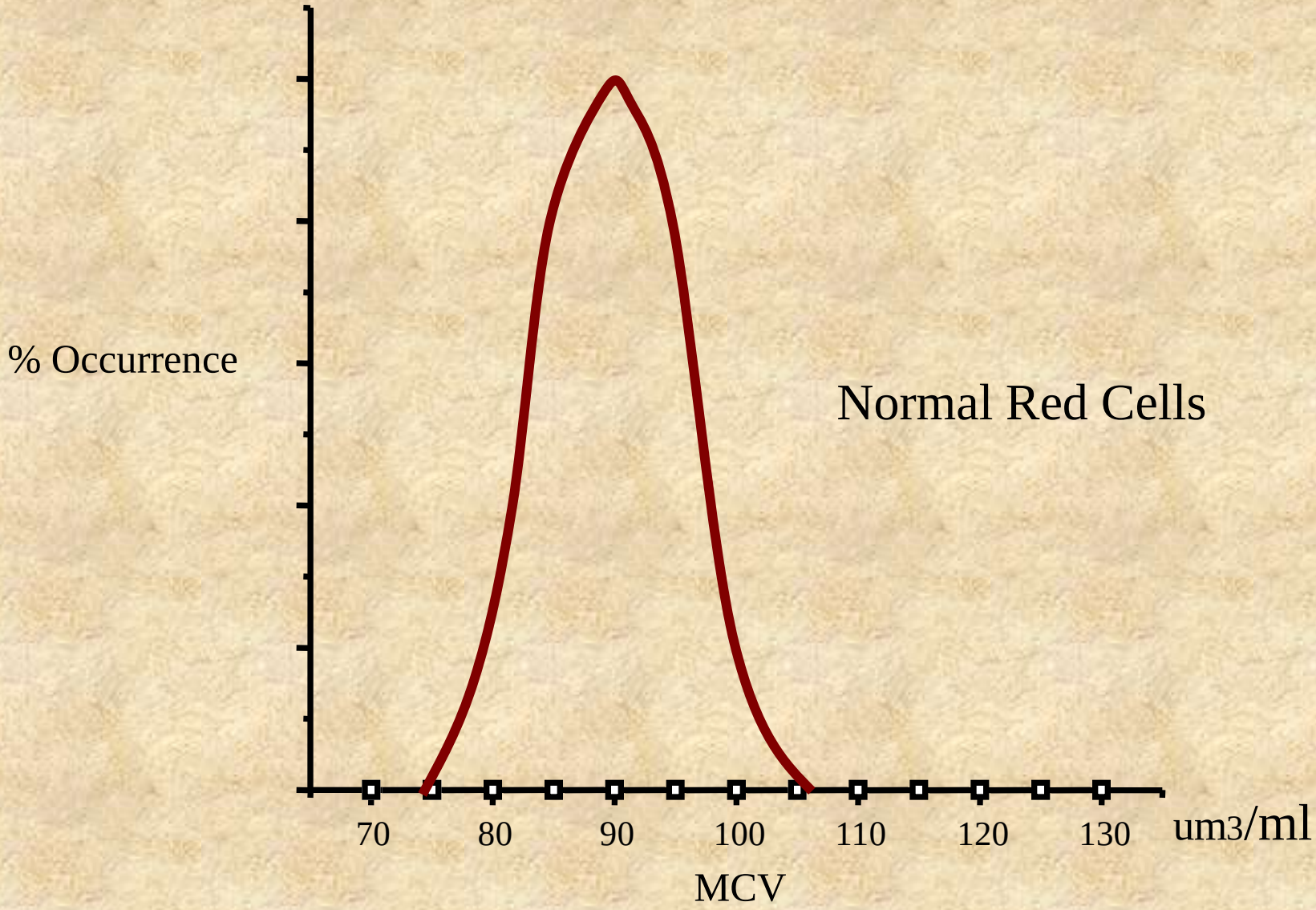
WBC count	7000	pre cubic millimeters of blood	
RBC count	5000000	pre cubic millimeters of blood	male
	4800000	pre cubic millimeters of blood	female

RBC indices

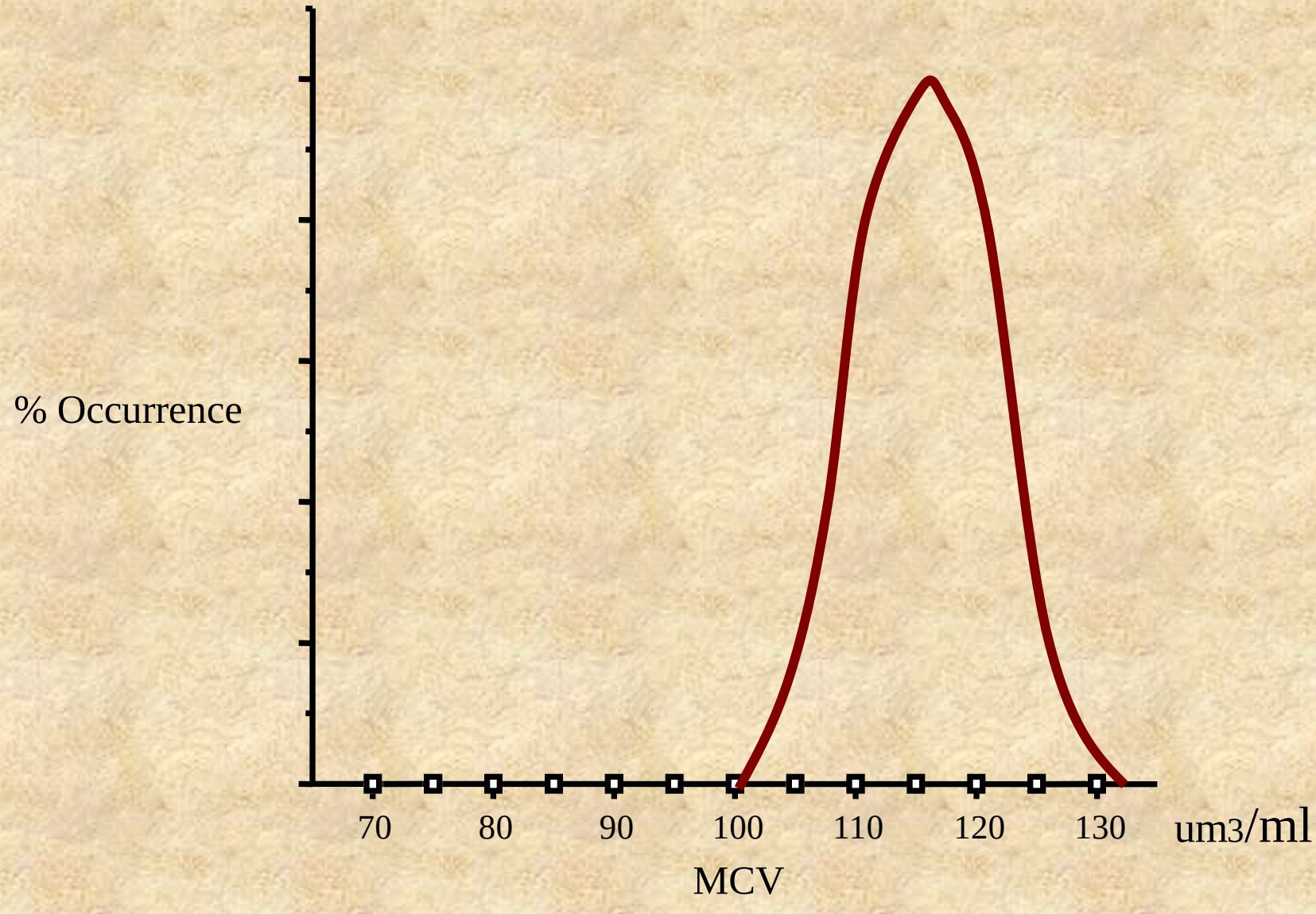
MCV (Mean cell volume) 90 cubic micrometer of blood

Platelet count 150000- 400000 pre cubic millimeters of blood

Normal Distribution of RBC Volumes



Increased RBC Volumes



Regulation of Red Cells Mass

Balance between production and destruction

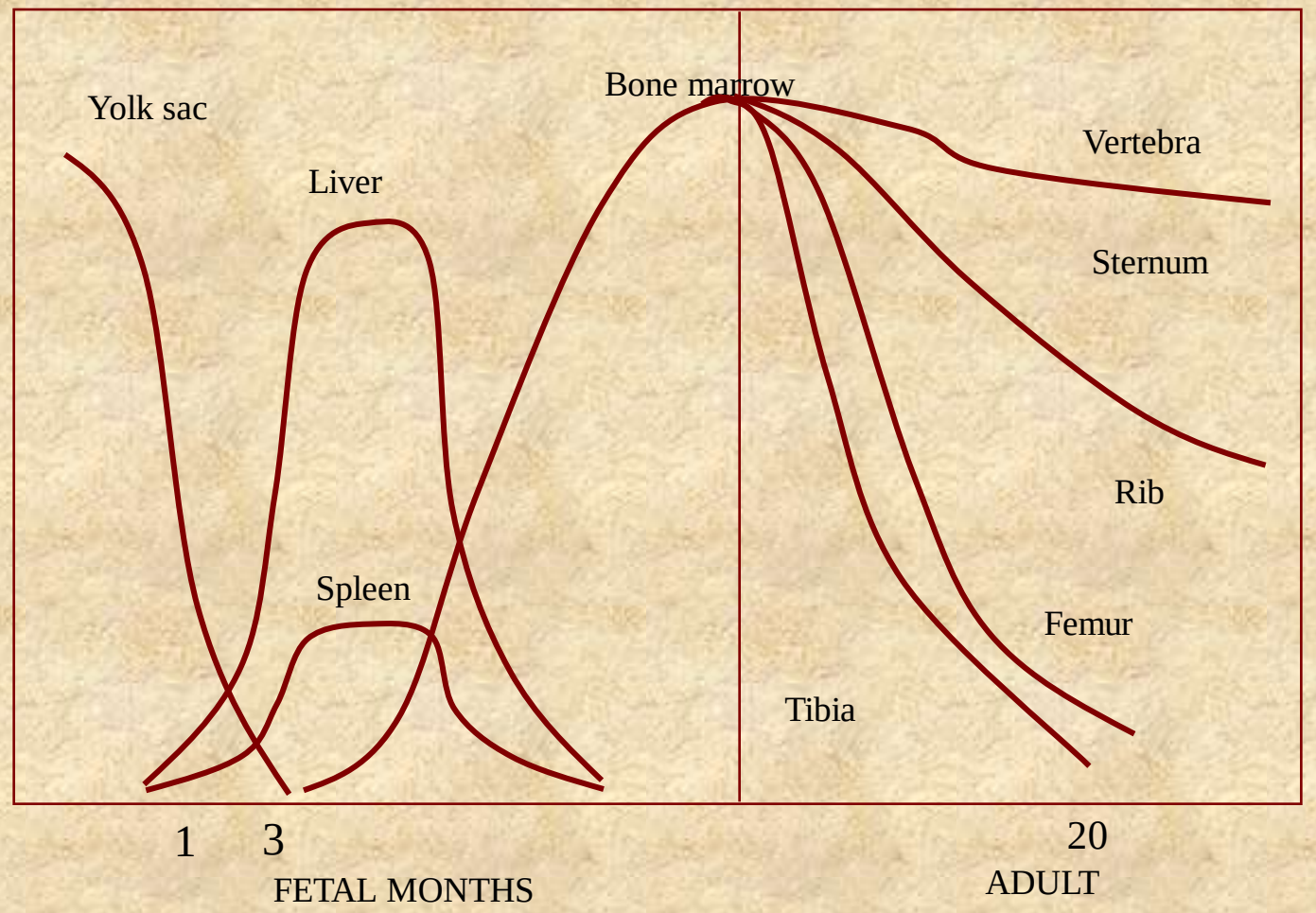
~ 1% produced/day ~ 1% destroyed/day

Produced in bone marrow

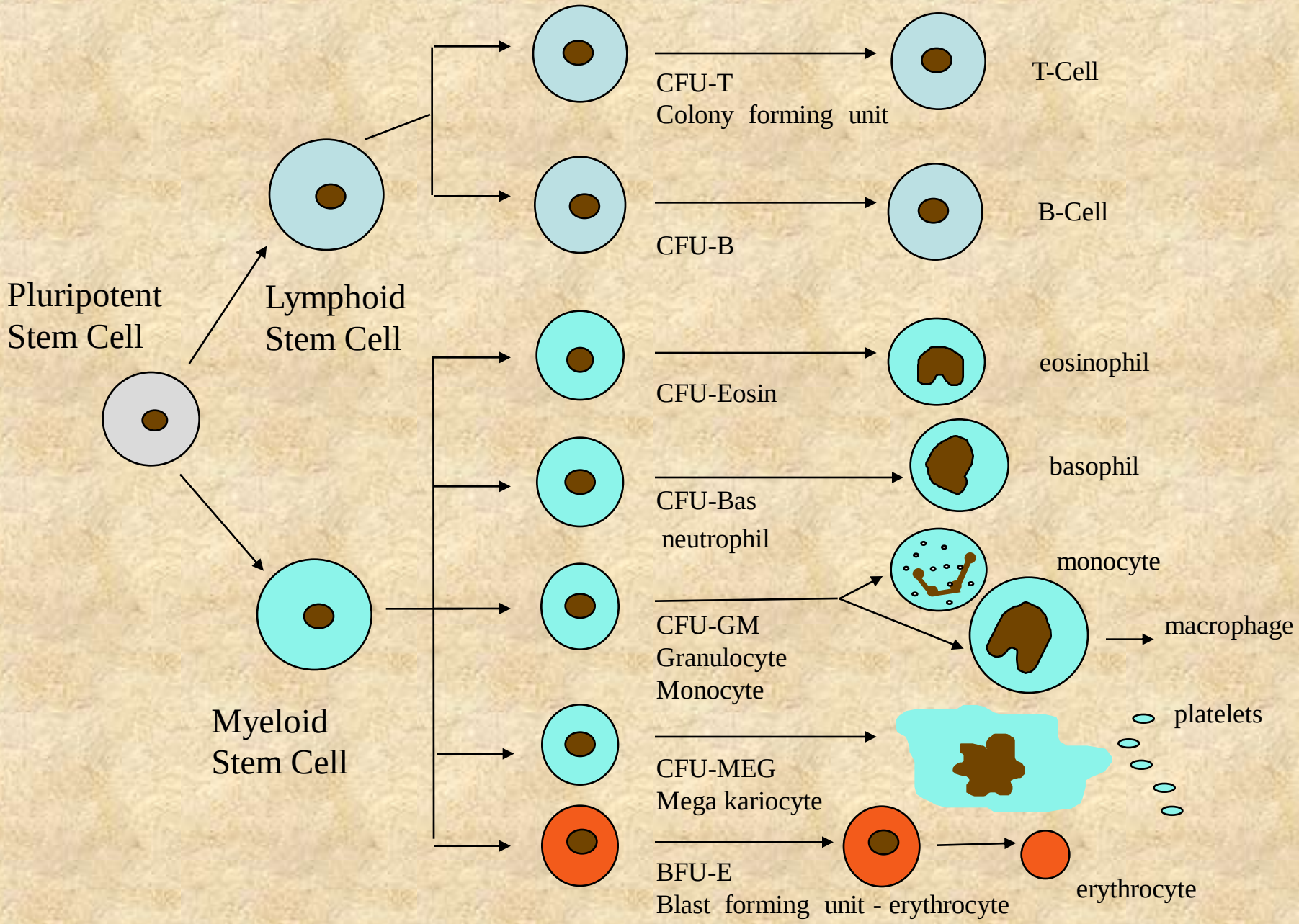
sternum, pelvis, vertebrae, ribs

Production regulated by erythropoietin

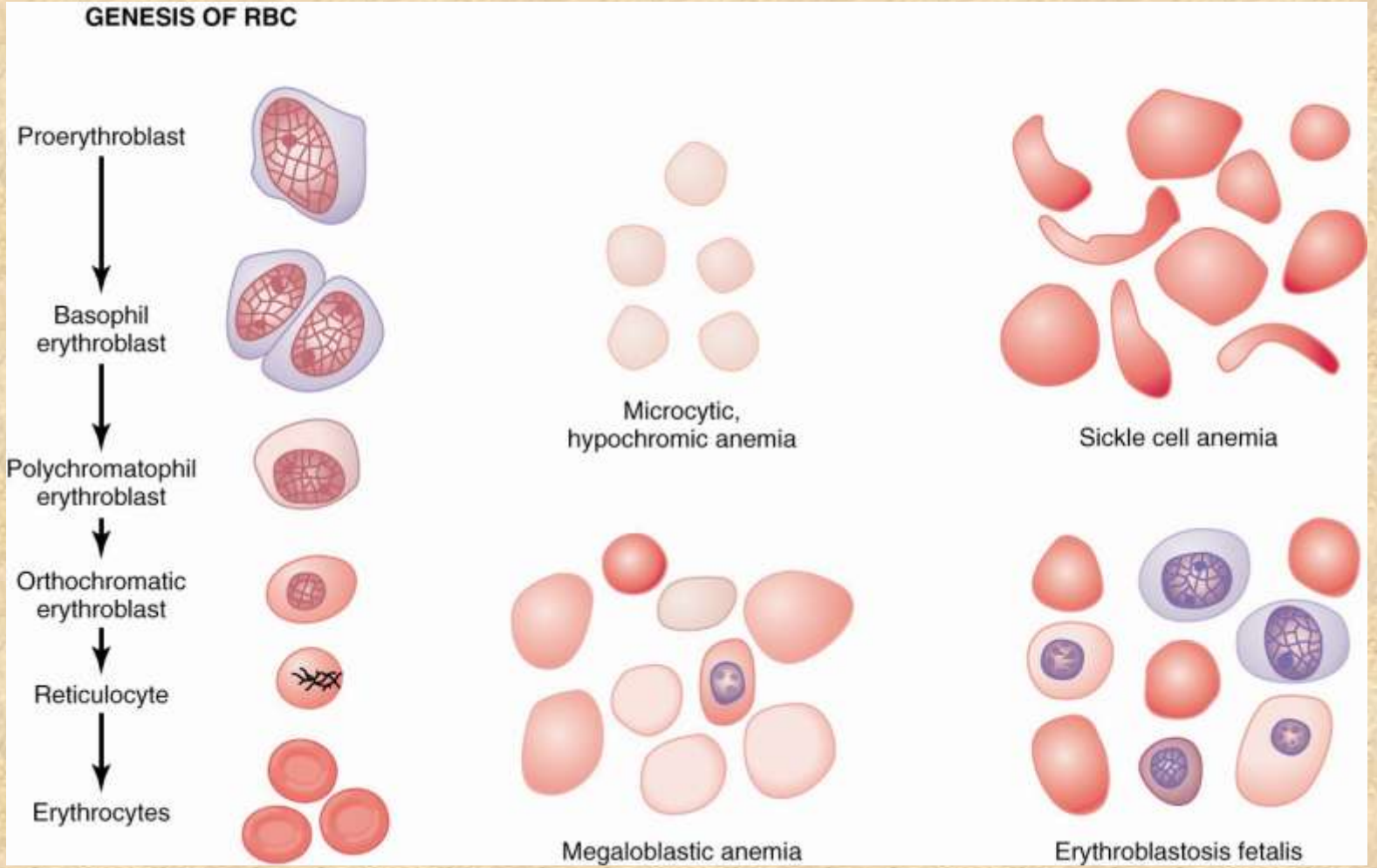
Sites Of Hemopoietic Activity



Genesis of Blood Products



Normal and Abnormal Production of RBCs



Erythropoietin

Hormone released from kidney in response to low renal oxygenation

Stimulates stem cells to form pronormoblasts

Promotes release of reticulocytes

Red cell production increases within 24 hours

Erythropoietin life span is 4-12 hours

Increase in red cell number in 5 days

Erythropoietin

Produced in peritubular interstitial cells of the kidney

Produced in the liver ~10%

No preformed stores of erythropoietin

Erythrocytosis suppresses erythropoietin production
but does not abolish it

Erythropoietin is always present in the plasma

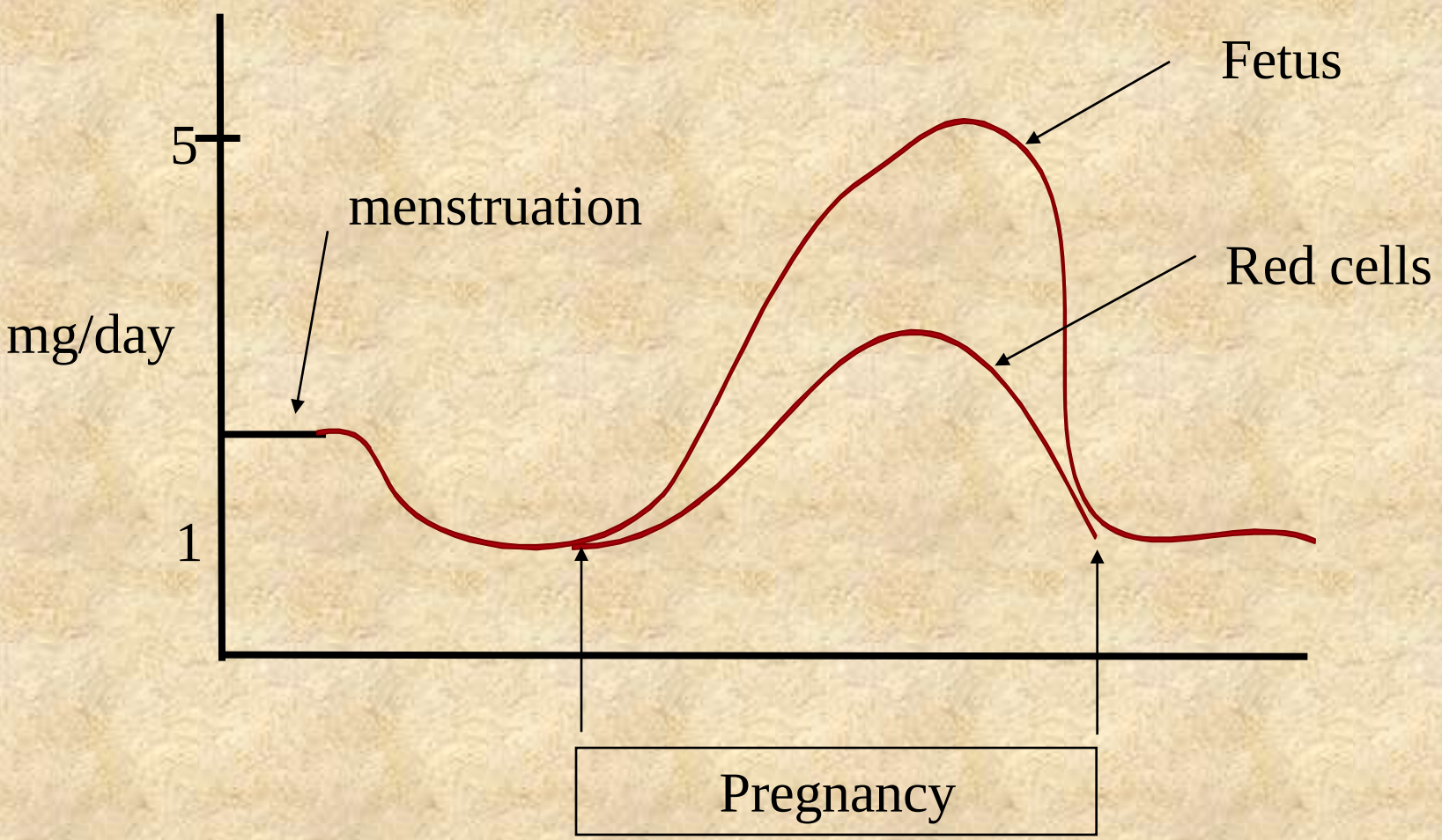
Destruction of Red Blood Cells

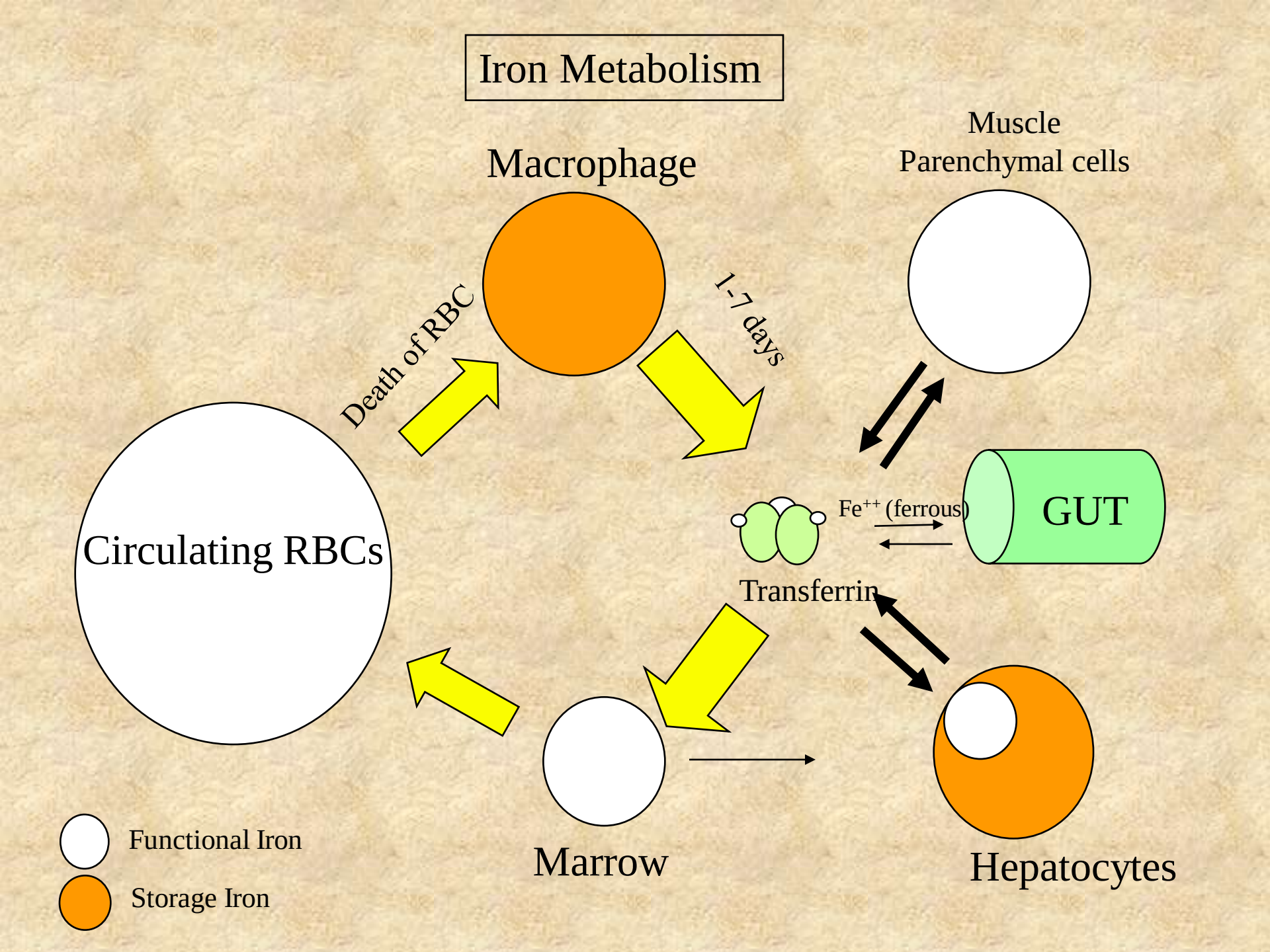
< 100 days survival hemolysis
Decrease in enzyme activity and ATP levels
Binding by IgG
Ingested by macrophage in spleen
Iron release to transferrin
Hemoglobin excreted as bilirubin

Iron Metabolism

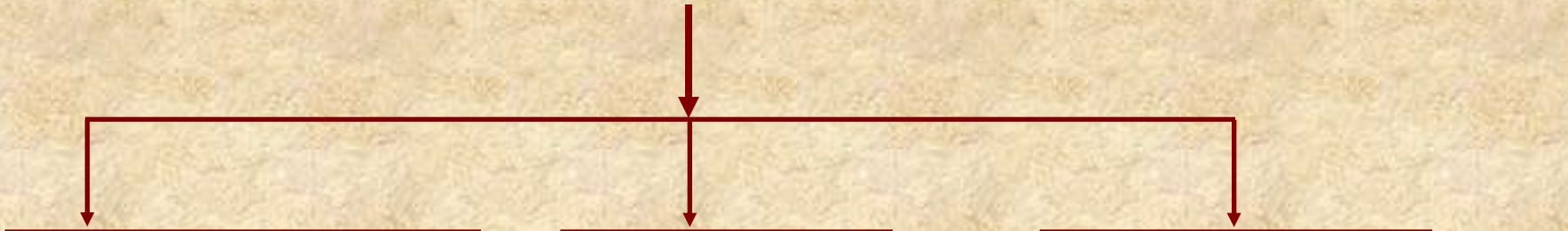
- **Daily Iron Requirements** 1-1.5 mg/day
- Iron storage 4 g
- absorption enhanced by meat, poultry, fish
- inhibited by carbonates, tannate (tea), oxalate (spinach), phosphates (vegetables), clay
- duodenum and upper jejunum major site absorption
- HCl promotes absorption
- loss 1 mg/day males average
- menstruating women additional 14 mg/period loss

Daily Iron Requirements




Iron Metabolism
Macrophage
Muscle
Parenchymal cells
Death of RBC
1-7 days
Circulating RBCs
Fe++ (ferrous)
GUT
Transferrin
Marrow
Hepatocytes
Functional Iron
Storage Iron

Anemia



Hypoproliferative
RI = low
(Reticulocyte index)

- Marrow Damage
- Stimulation
  - Renal disease
  - Inflammation
  - Metabolic disease
- Iron deficiency

Maturation Disorders
RI = low

- Cytoplasmic defects
  - Thalassemia
- Nuclear maturation defect
  - Folate deficiency
  - Vit B_{12} deficiency

Hemorrhage/ Hemolysis
RI = high

- Blood loss
- Intravascular hemolysis
- Autoimmune
- Metabolic membrane
- Hemoglobinopathy

Classification of Anemias

MCV (fl)	Hgb Content (MCHC) (g/dl) Mean corpuscular Hemoglobin concentration	Causes
Normocytic (80-100)	Normochromic (32-36)	Bone marrow failure, renal disease, hemolytic anemia
Macrocytic (>100)	Normochromic (32-36)	Megaloblastic anemia
Microcytic (<80)	Hypochromic (<32)	Iron deficiency, chronic diseases

Hypoproliferative

- Aplastic anemia
  - Primary
    - idiopathic
  - Secondary
    - Drugs - chemotherapy, antibiotics, antidepressants, ethanol
    - Chemicals - benzene
    - Radiation
    - Immune suppression of stem cell
    - Malignancy (non-hematopoietic tumors and transformation of hematopoietic stem cells)
  - Therapy

Hypoproliferative

- Reduced erythropoietin response
  - Acute inflammatory state
    - acute, chronic bacterial infections
    - AIDS (Acquired immunity disease syndrome)
  - Renal Disease
  - Hypometabolic state
    - protein deprivation
    - endocrine deficiency
      - hypothyroidism
      - hypopituitarism
  - Therapy

Hypoproliferative

- Iron deficiency
  - almost always blood loss
  - exceptions (children, adults poor absorption)
- Men and post menopausal women
  - GI blood loss
- depletion of stores
- decrease iron - microcytic, hypochromic
- major deficiency misshapen RBCs

Maturation defects

- Thalassemia
  - South European, African, Asian
  - defect in hemoglobin synthesis
  - microcytic, hypochromic
  - transfusions, folic acid

Megaloblastic Anemias

Large fragile red blood cells
Impaired DNA synthesis
Increased utilization
Folic Acid Deficiency
- Inadequate diet, Dialysis, cirrhosis, vegetarian
- Impaired absorption
- Folate very heat labile

Vitamin B12 Deficiency
- Inadequate diet
- Dialysis
- Impaired absorption
- Intrinsic factor (glycoprotein secreted by gastic parietal cells) (Pernicious anemia)

Hemolytic, Blood Loss

- Hereditary
  - Sickle cell (hemoglobin)
  - Spherocytosis (membrane)
- Acquired
  - Microangiopathic hemolytic anemia
  - Immune responses, mismatch typing
- Blood Loss

Polycythema

Three Pathophysiological Categories of Polycythemia
1.Relative Polycythemia (Red Blood Cell Mass Normal, Plasma Volume Decreased)
2.Secondary Polycythemia (Red Blood Cell Mass Increased)
3.Polycythemia vera (Red Blood Cell Mass Increased)

	Polycythemia Vera	Secondary Polycythemia
Pathophysiology	Stem Cell Disorder	Tissue hypoxia increasing EPO (**Erythropoietin**) production or due to renal or hepatic disease causing inappropriate increase in EPO production
CBC (complet blood count)	Hct and often WBC and platelets are increased	Only Hct is increased
EPO level **(Erythropoietin)**	Decreased or low normal	Normal or increased
Treatment	Phlebotomy	Treatment not required