Principles of Physiology For

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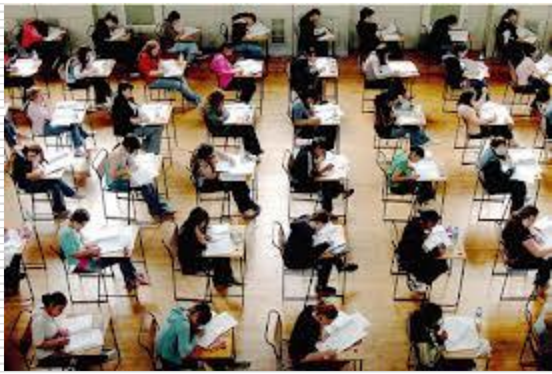
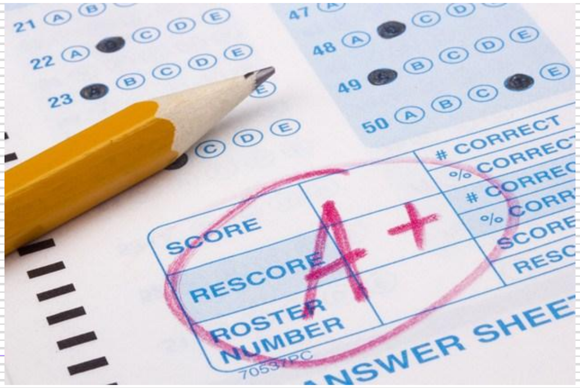
Zoology course

- **Total = 100 marks**
  - Mid-Term = 15 marks
    - [7.5 1^{st} term +7.5 2^{nd} term]
  - Practical = 20 marks
    - [10 1^{st} term +10 2^{nd} term]
  - Oral = 15 marks
  - **Final Exam = 50 marks**





Blood ,,,,ILOS

- By the end of the lecture you should be able to:
- State the Function &composition of Blood
- State the function of red blood cells, Leukocytes and plasma
- State the function of macrophages and lymphocytes

Blood Function

- **Nutritional**: transport of digested food from gut to tissue.
- **Respiratory**: Transport O_2 and Co_2 between lung and tissue.
- **Excretory:** Carries waste (Co_2, Urea and lactic acid) away from cells.
- **Regulatory:** Regulation of body PH. and Regulation of core body temperature.

Blood Function

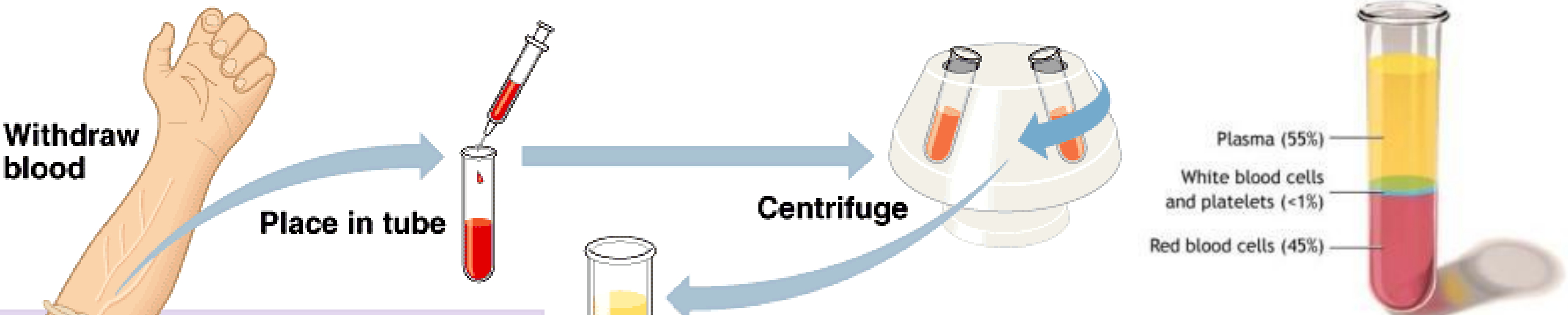
- **Protective:**
  - Carries various disease-fighting cells such as the "white" blood cells.
  - Part of the body's self-repair mechanism (blood clotting in order to stop bleeding - using 'Platelets')

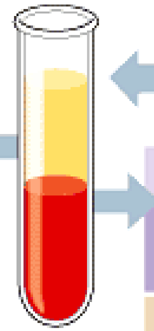
what's in

BLOOD

- digested food
- red blood cells
- white blood cells
- oxygen
- waste (urea)
- Plasma
- carbon dioxide
- hormones
- platelets

The composition of human blood

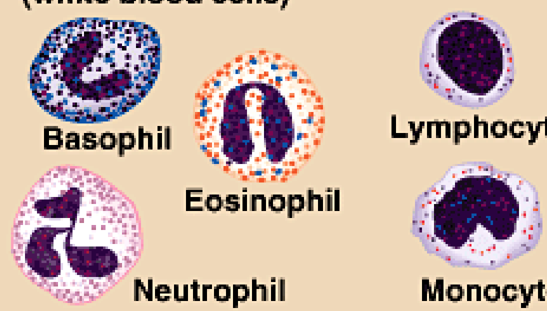




Plasma 55%

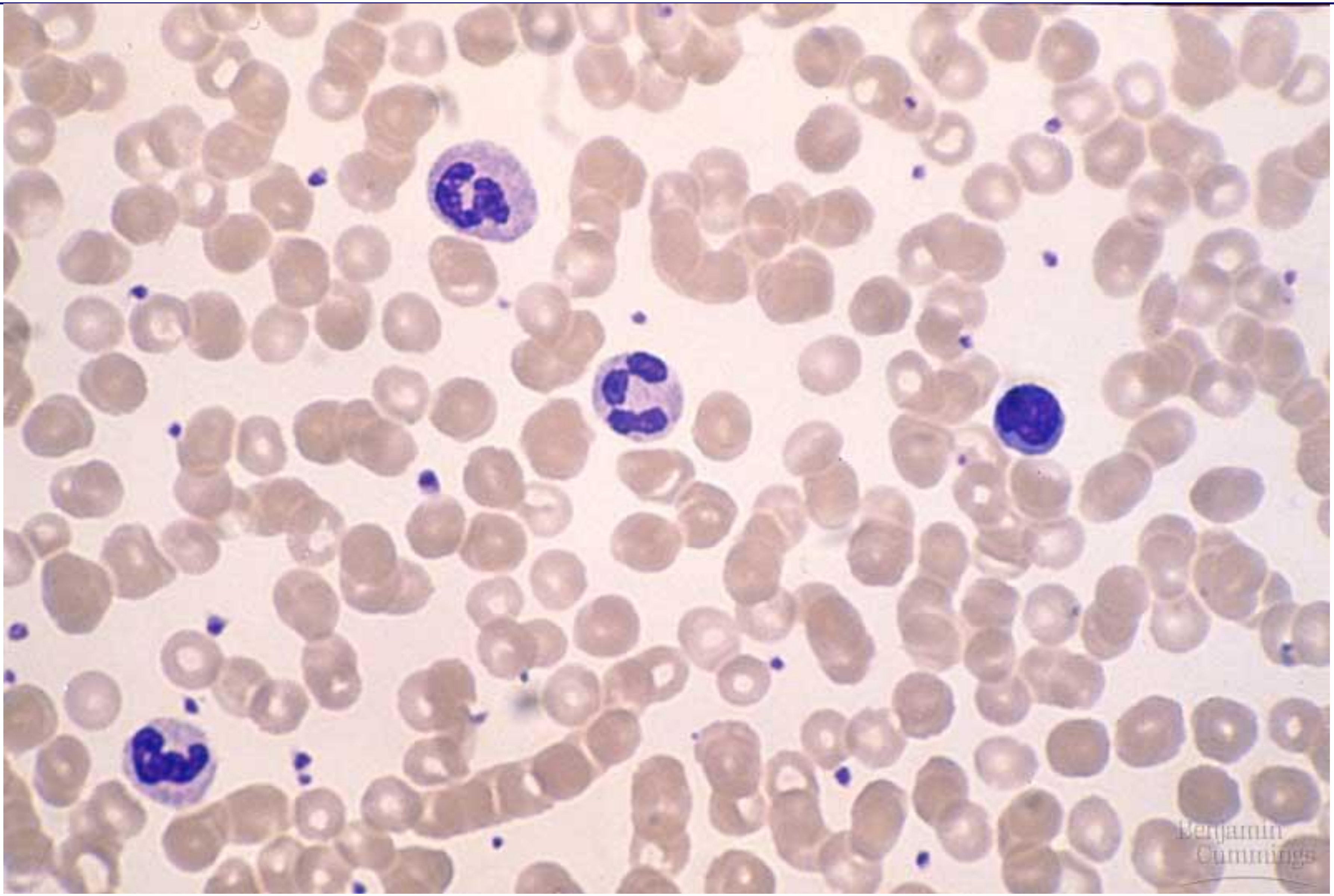
Constituent	Major functions
Water	Solvent for carrying other substances
Ions Sodium Potassium Calcium Magnesium Chloride Bicarbonate	Osmotic balance, pH buffering, and regulation of membrane permeability
Plasma proteins Albumin Fibrinogen Immunoglobulins (antibodies)	 Osmotic balance pH buffering Clotting Defense
Substances transported by blood Nutrients (e.g., glucose, fatty acids, vitamins) Waste products of metabolism Respiratory gases (O_2 and CO_2) Hormones	

Cellular elements 45%

Cell type	Number (per mm^3 of blood)	Functions
Erythrocytes (red blood cells) 	5–6 million	Transport oxygen and help transport carbon dioxide
Leukocytes (white blood cells) 	5000–10,000	Defense and immunity
Platelets 	250,000–400,000	Blood clotting

In average human has 5 litres of blood

Blood smear



Components of the Blood

- **Plasma** fluid part of blood made up of dissolved ions and various organic molecules

  3 types of plasma proteins

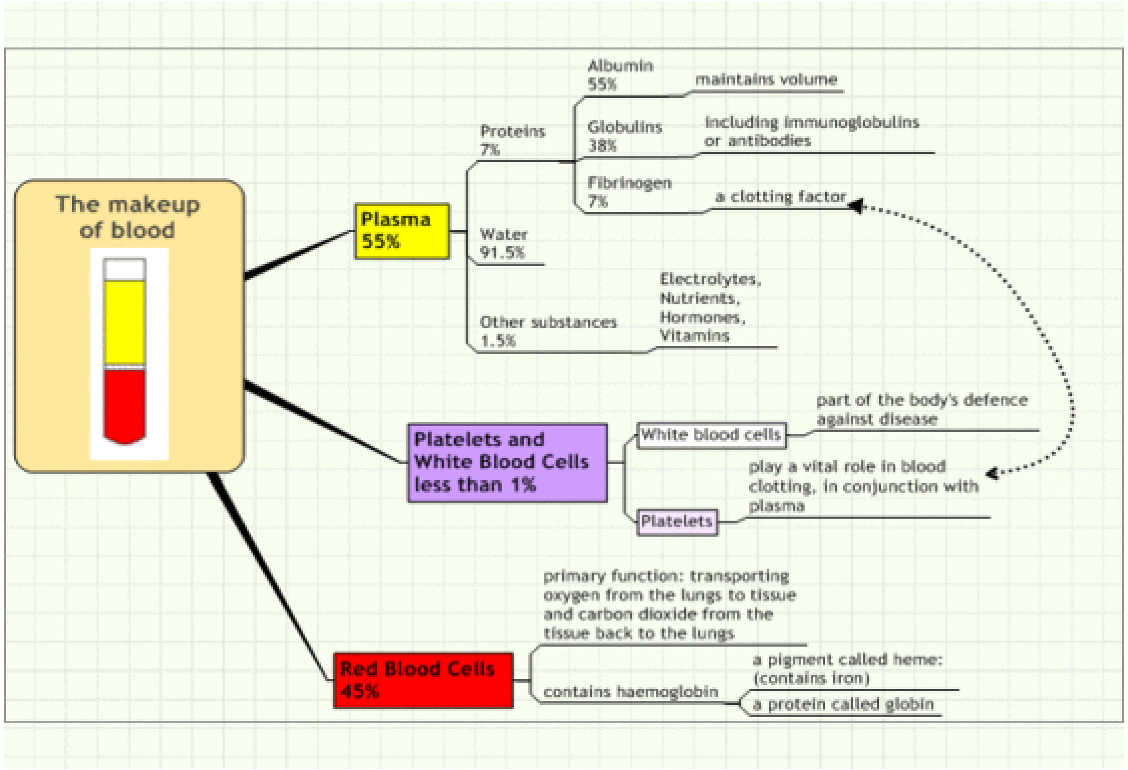
  - **Albumin** - creates osmotic pressure that moves water from interstitial fluid to capillaries
  - **Globulins** - Alpha, beta, and gamma
  - **Fibrinogen** - helps with clotting and converts to fibrin where the fluid serum is left after clotting

Components of the Blood

- **Formed elements**
  - **Erythrocytes** - Red Blood Cells that contain hemoglobin and transport oxygen
  - **Leukocytes** - White Blood Cells that help with immunity and can be granular (eosinophils, basophils, and neutrophils) or agranular (lymphocytes and monocytes)
  - **Platelets** - required for blood clotting

Important terms

- **Hematopoiesis** - formation of blood cells from stem cells in bone marrow and lymphoid tissue
  - **Erythropoiesis** - forms Red Blood Cells (RBCs)
  - **Leukopoiesis** - forms White Blood Cells (WBCs)



The makeup of blood
Plasma 55%
Proteins 7%
Albumin 55%
maintains volume
Globulins 38%
including immunoglobulins or antibodies
Fibrinogen 7%
a clotting factor
Water 91.5%
Other substances 1.5%
Electrolytes, Nutrients, Hormones, Vitamins
Platelets and White Blood Cells less than 1%
White blood cells
part of the body's defence against disease
Platelets
play a vital role in blood clotting, in conjunction with plasma
Red Blood Cells 45%
primary function: transporting oxygen from the lungs to tissue and carbon dioxide from the tissue back to the lungs
contains haemoglobin
a pigment called heme: (contains iron)
a protein called globin

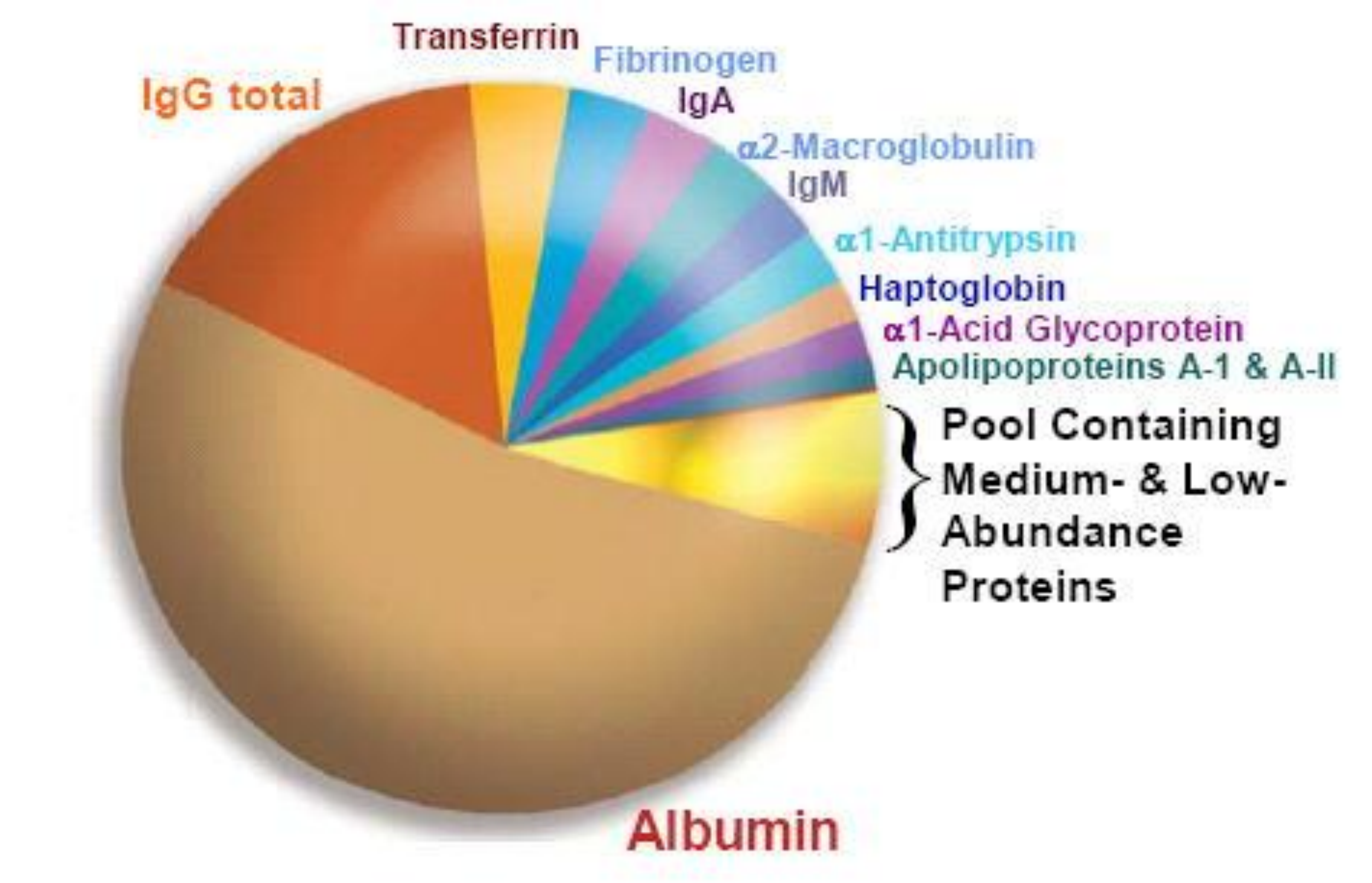
Plasma Proteins

- Constitute 7-9% of plasma
- Three types of plasma proteins: albumins, globulins, & fibrinogen
  - **Albumin** accounts for 60-80%
    - Creates colloid osmotic pressure that draws H_20 from interstitial fluid into capillaries to maintain blood volume & pressure
- **Globulins** carry lipids
  - Gamma globulins are antibodies
- Fibrinogen serves as clotting factor
  - Converted to fibrin

What is plasma and serum?

- **Serum** is the liquid part of blood AFTER coagulation (clots) , therefore devoid of clotting factors as fibrinogen.
- **Plasma** is the liquid, cell-free part of blood, that has been treated with anti-coagulants.

Plasma Proteins

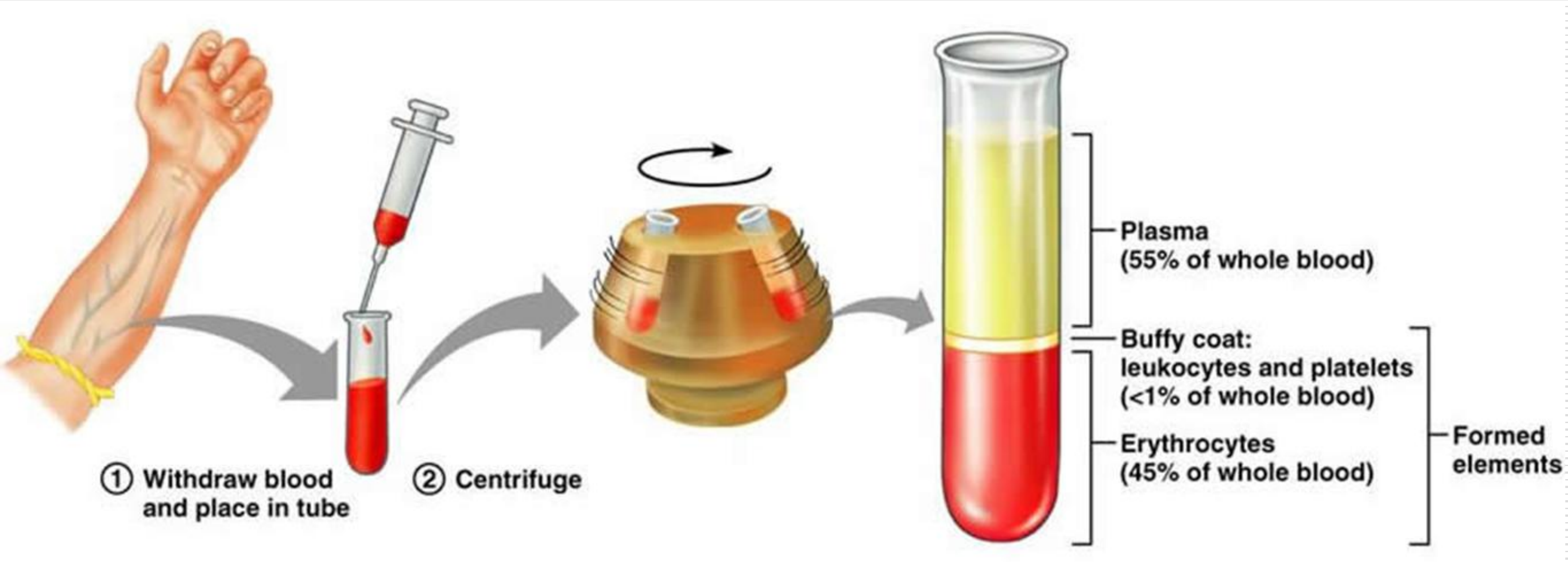


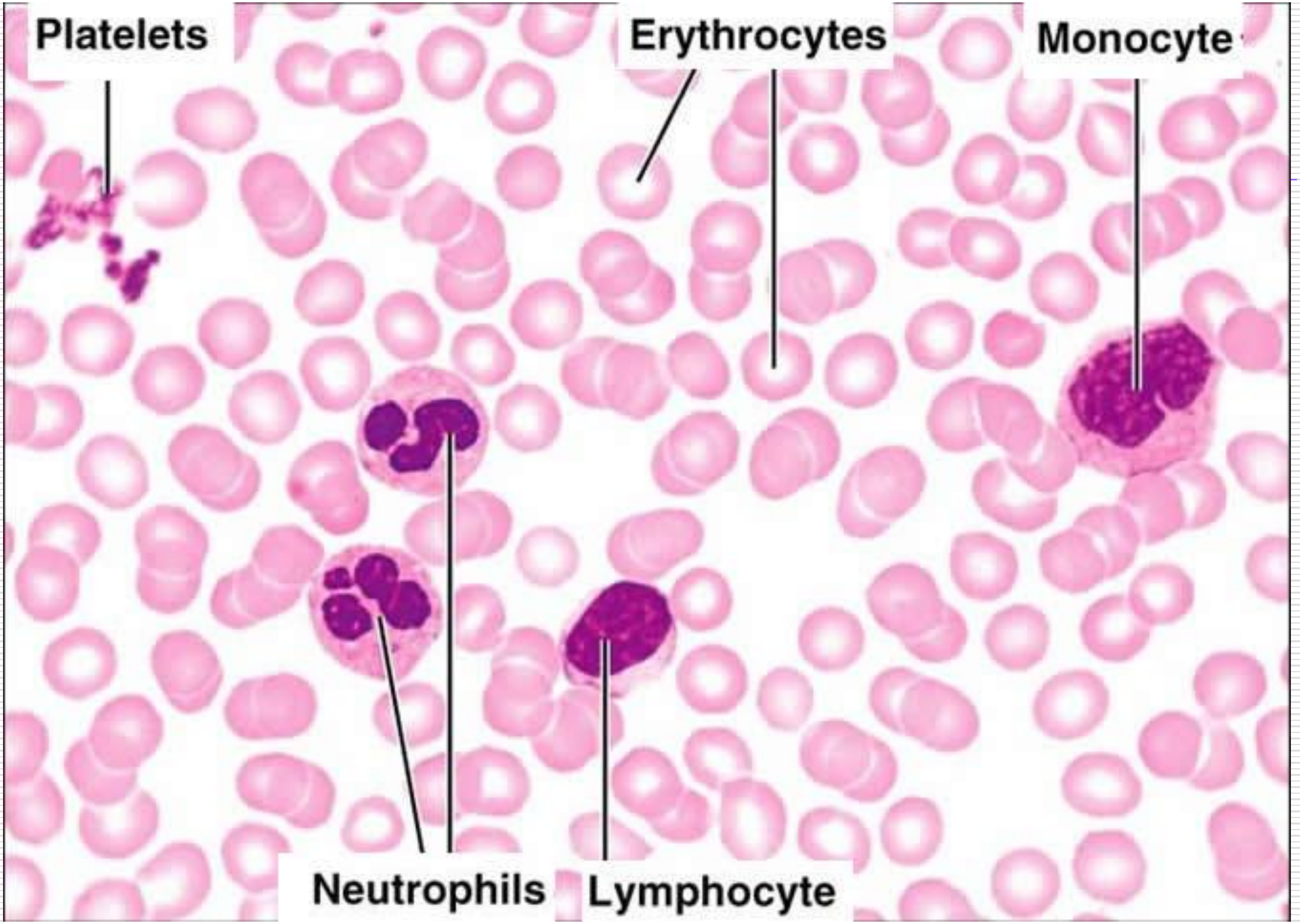
Function of plasma proteins

- Regulate blood osmotic pressure (albumin)
- Transport nutrients and hormones.
- Protection against infection (γ-globulin
- Formation of blood clot (fibrinogen)

Blood
Physical Characteristics and Volume

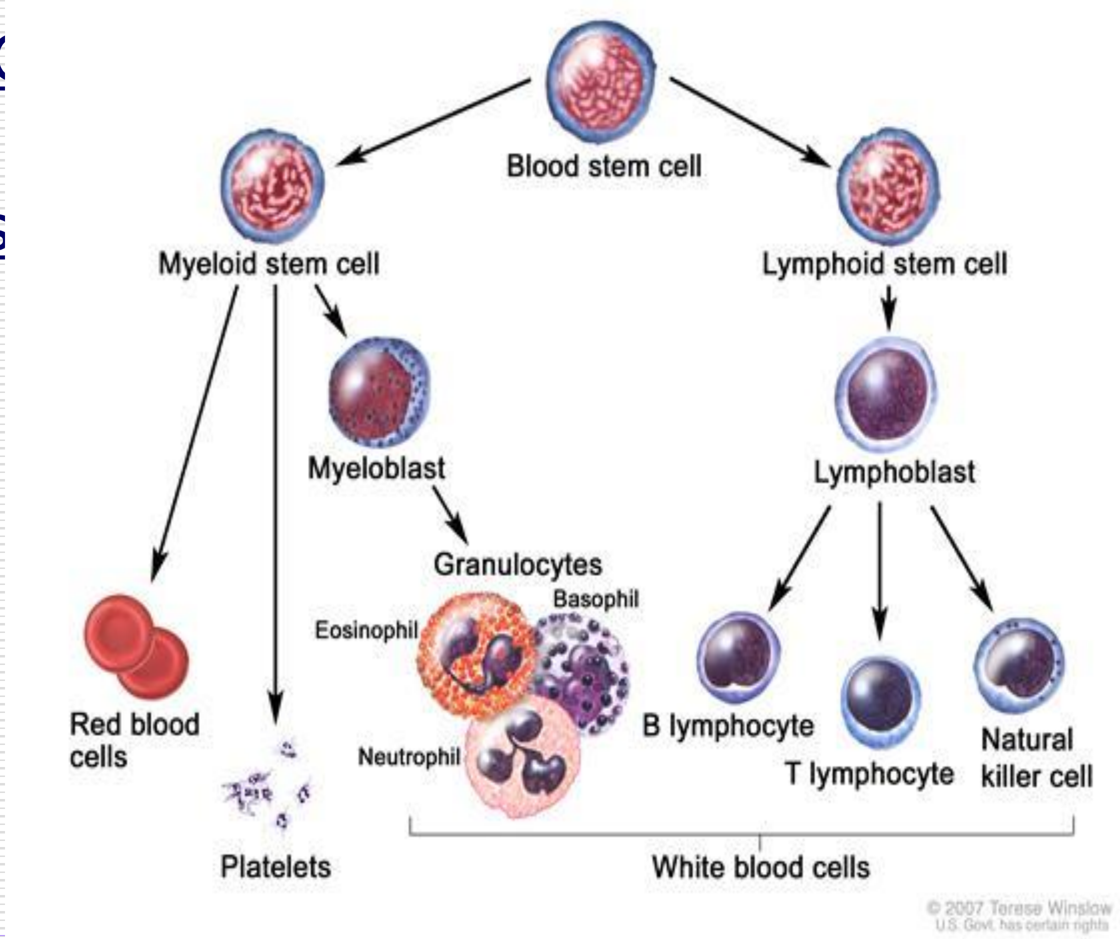
- slightly basic (pH = 7.35–7.45)
- Normal blood volume in males is 5-–6 liters, and 4–5 liters for females.



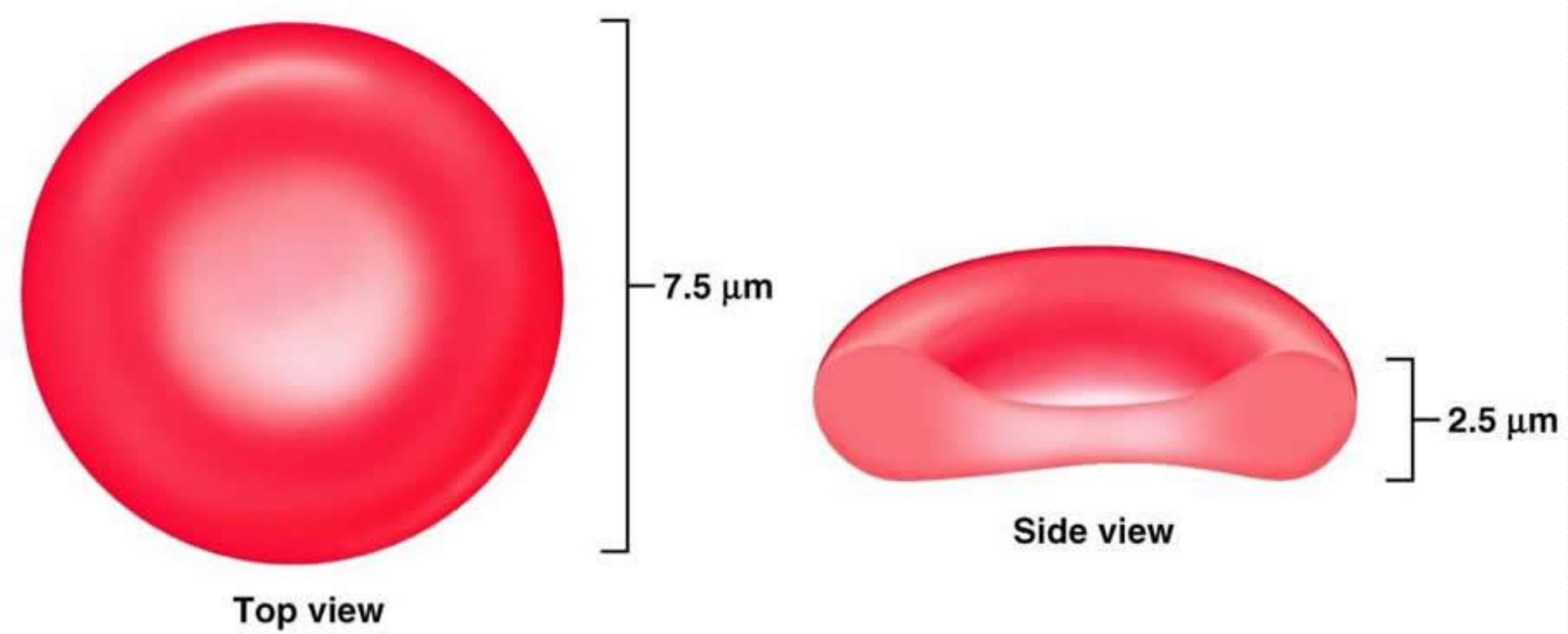

Platelets
Erythrocytes
Monocyte
Neutrophils
Lymphocyte

Formed Elements

- **Erythrocytes** (RB
  - $5\text{-}6X10^6$ /mm^3
- **Leukocytes**(WBCs
  - $7X10^3$/mm^3
  - **Granulocytes**
    - Lymphocytes
    - Monocytes
  - **Agranulocytes**
    - Neutrophile
    - Basophile
    - Acidophile
- **Platelets**
  - $3X10^5$/mm^3

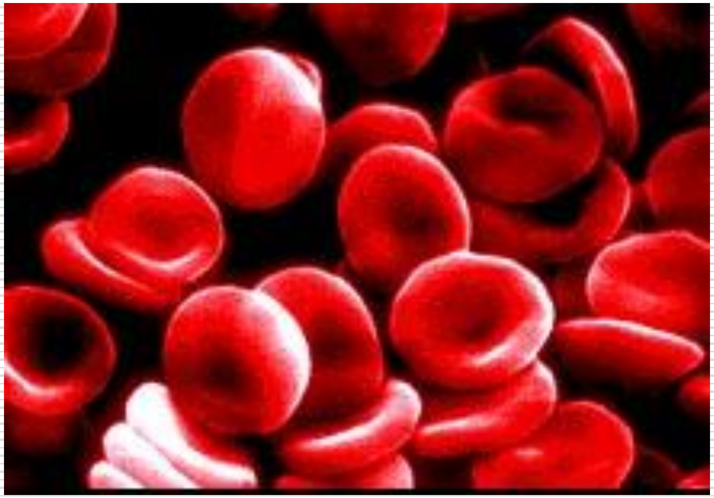


Erythrocytes



Red blood cells

1) Flattened & biconcave shape



increases the surface area so more oxygen can be carried

2) <u>no</u> **nucleus** & **mitochondria**

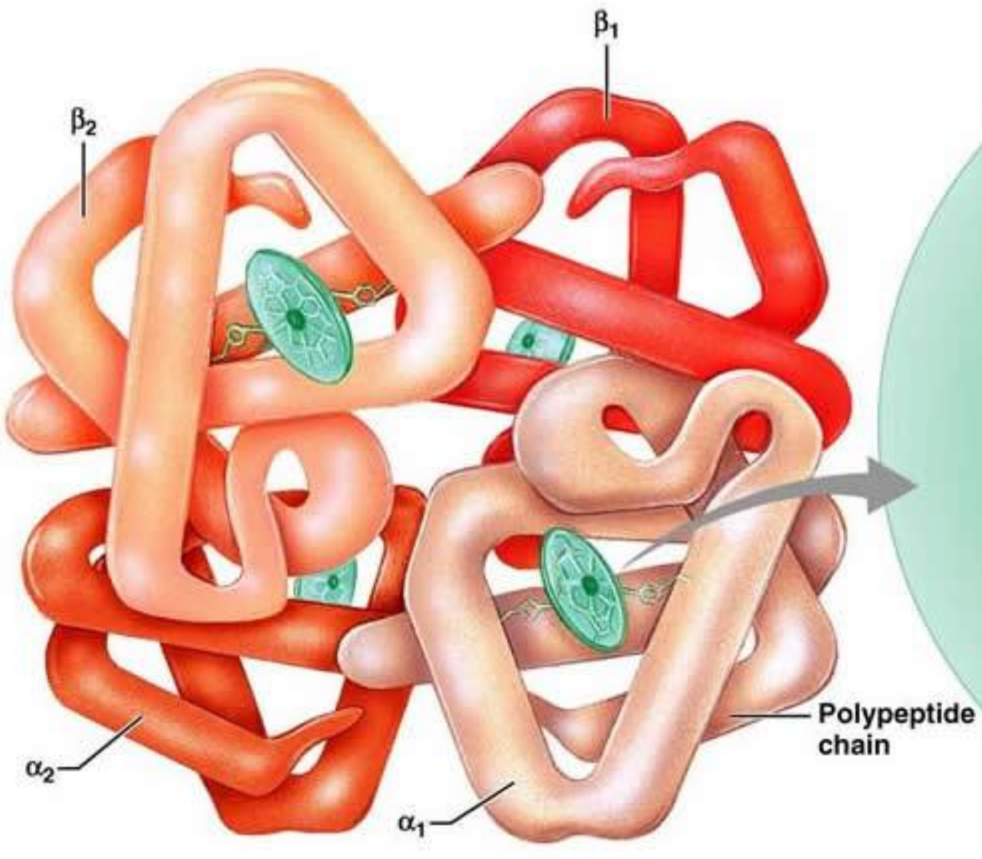
→ extra space inside

3) contain **<u>haemoglobin</u>**

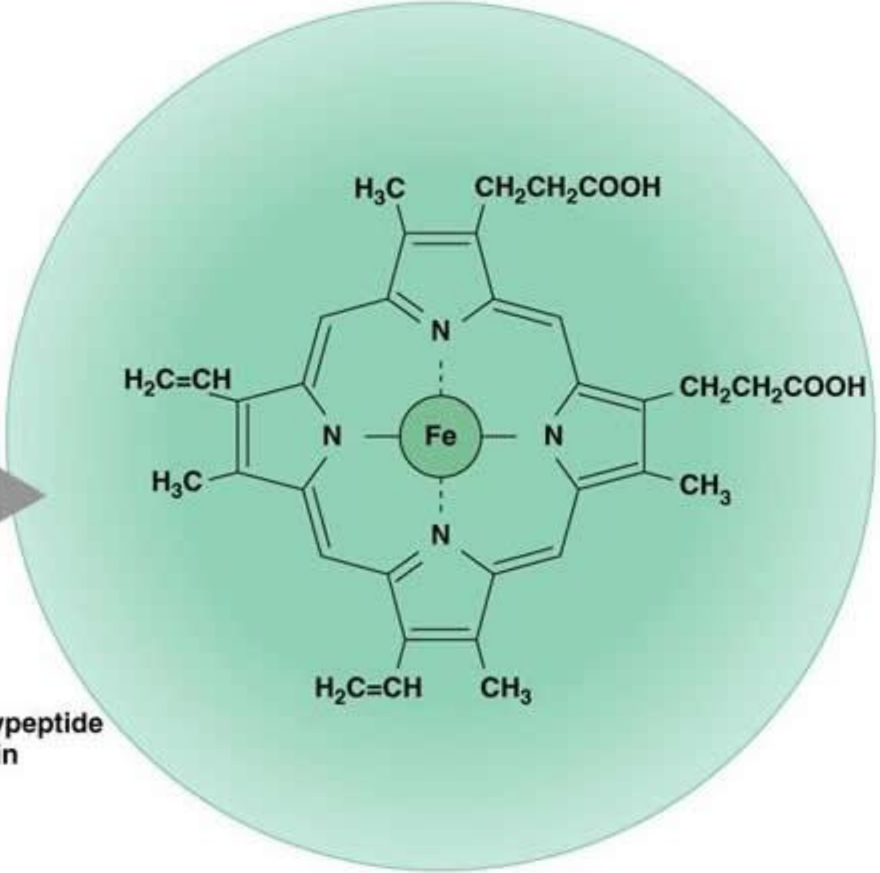
→ the oxygen carrying molecule

4) **Count: 5-6 milions** per mm^3

Hemoglobin



(a) Hemoglobin



(b) Iron-containing heme group

Red Blood Cells

- **Red blood cell production**

In the embryo and fetus, red blood cell production occurs in the yolk sac, liver, and spleen; after birth, it occurs in the red bone marrow.

The average life span of a red blood cell is 120 days.

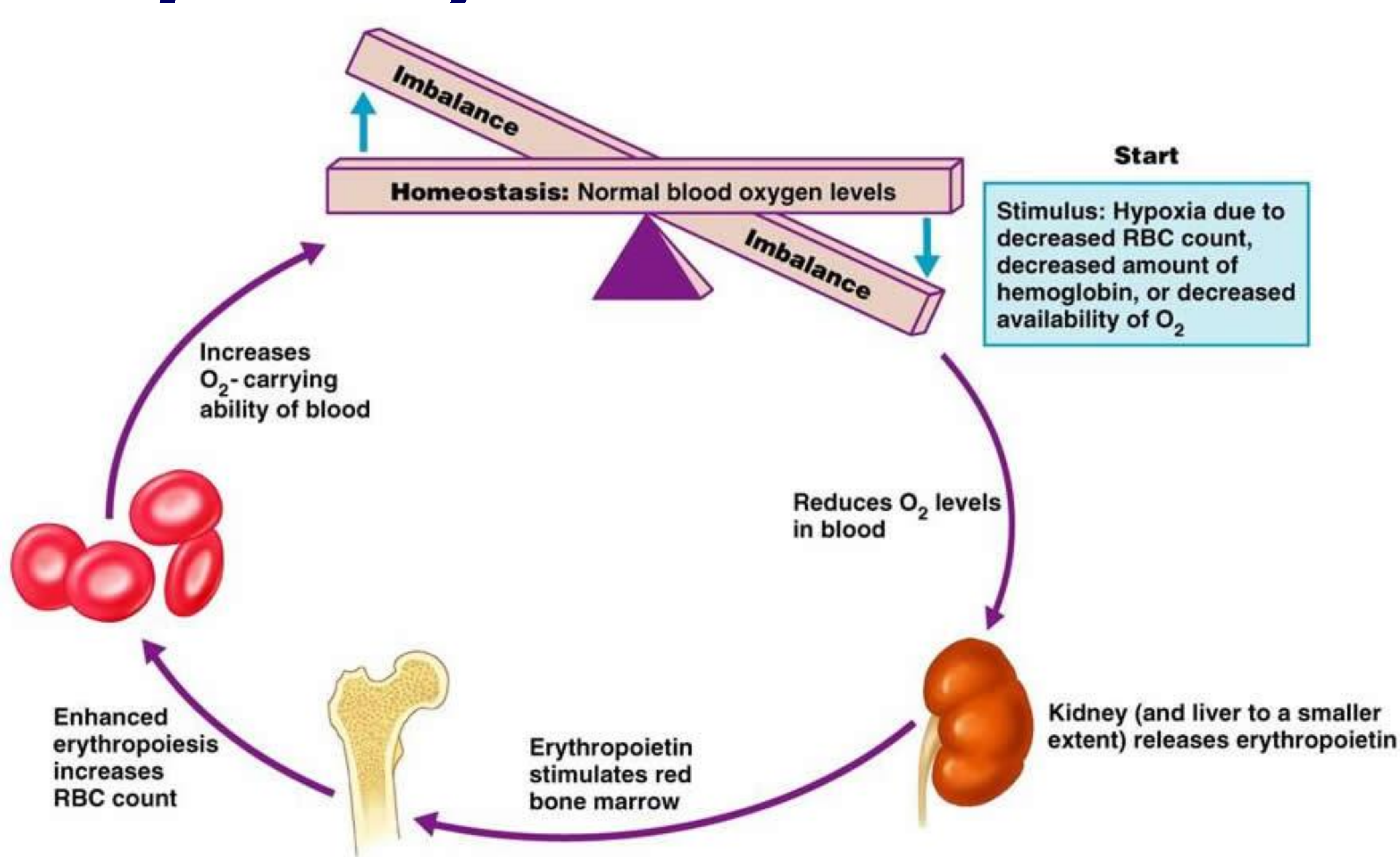
Erythrocyte Production

The total number of red blood cells remains relatively constant.. Why??

due to a negative feedback mechanism utilizing the hormone erythropoietin, which is released from the kidneys and liver in response to the detection of low oxygen levels.

Any thing else????

Erythrocyte Production

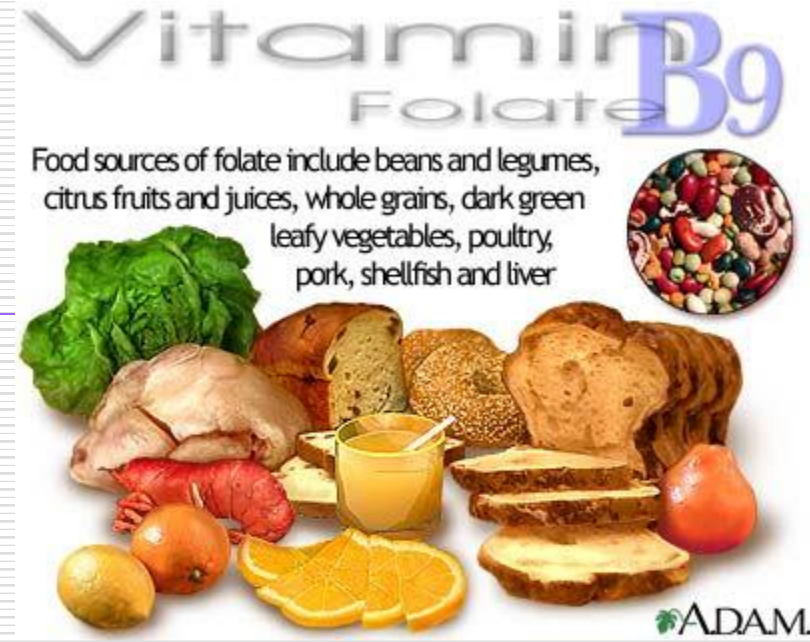


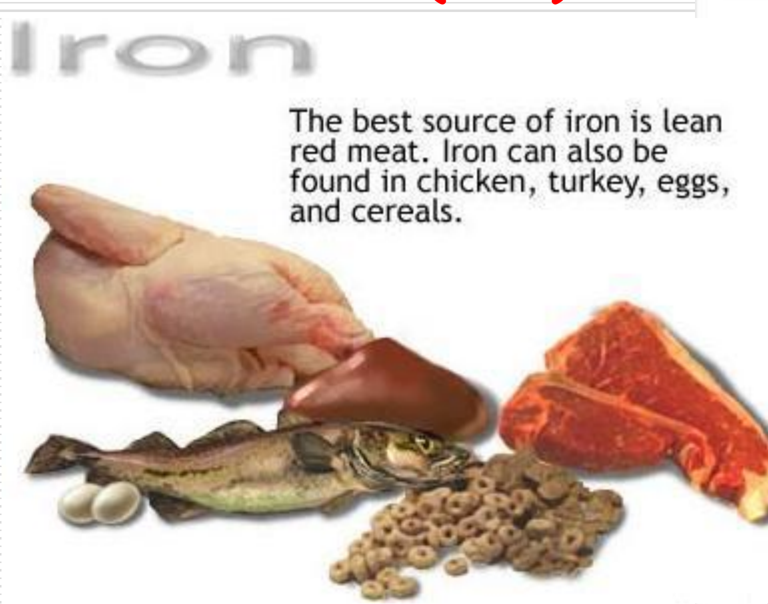
Erythrocyte Production

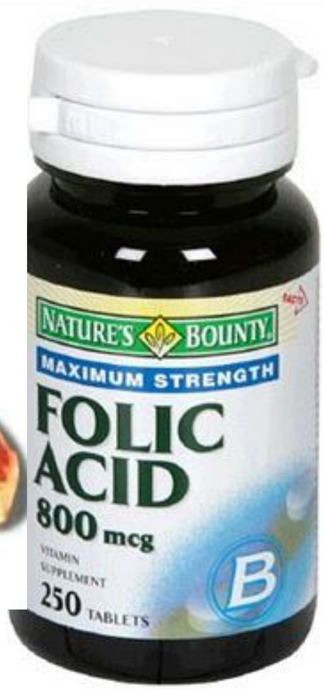
- Any thing else????

Erythrocyte Production

- Vit B 9(Folic acid)
- Vitamins B_{12},
- Iron (Fe)







Red Blood Cells

- **Red blood cell destruction**

  With age, red blood cells become increasingly fragile and are damaged by passing through narrow capillaries.

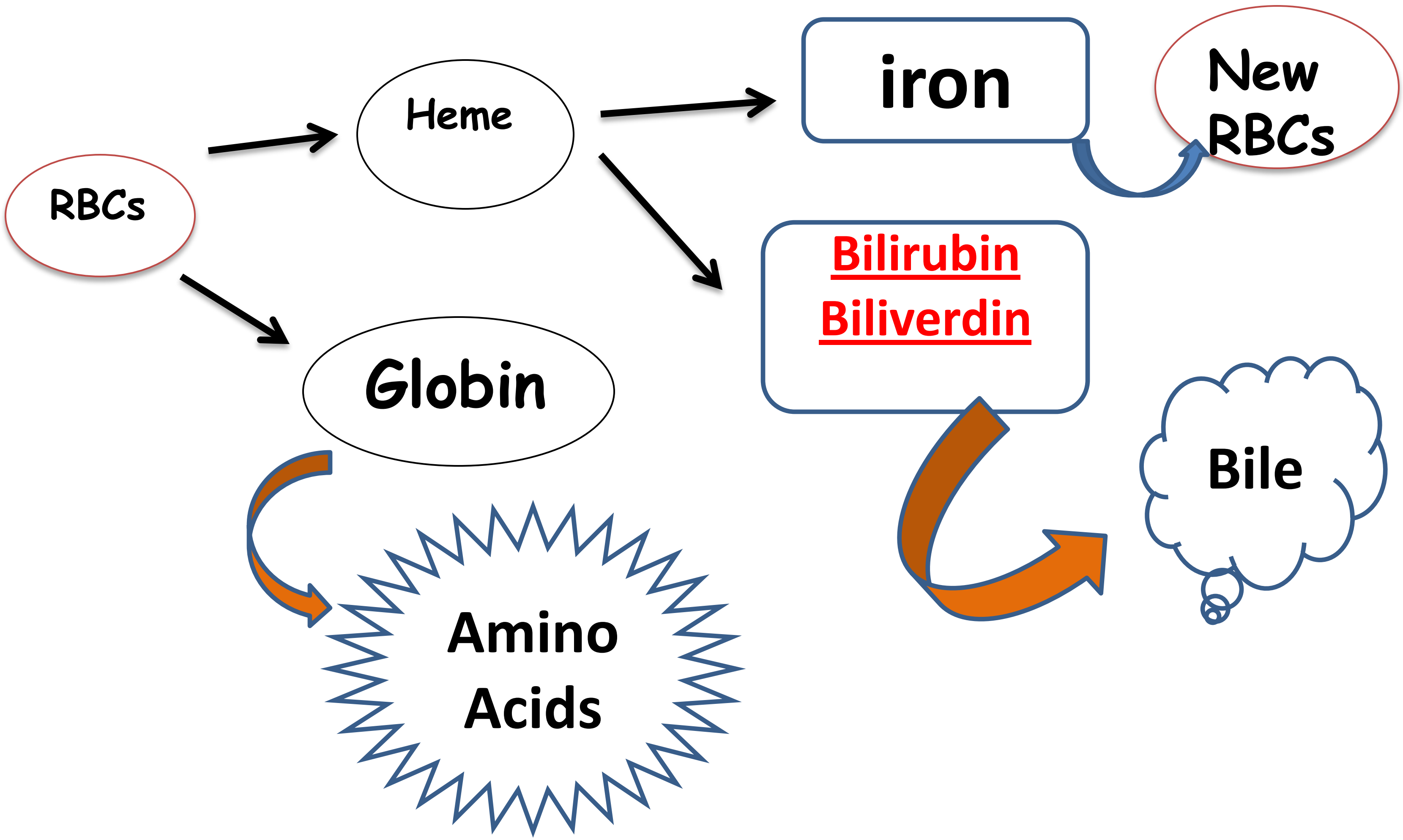
  Macrophages in the liver and spleen phagocytize damaged red blood cells.

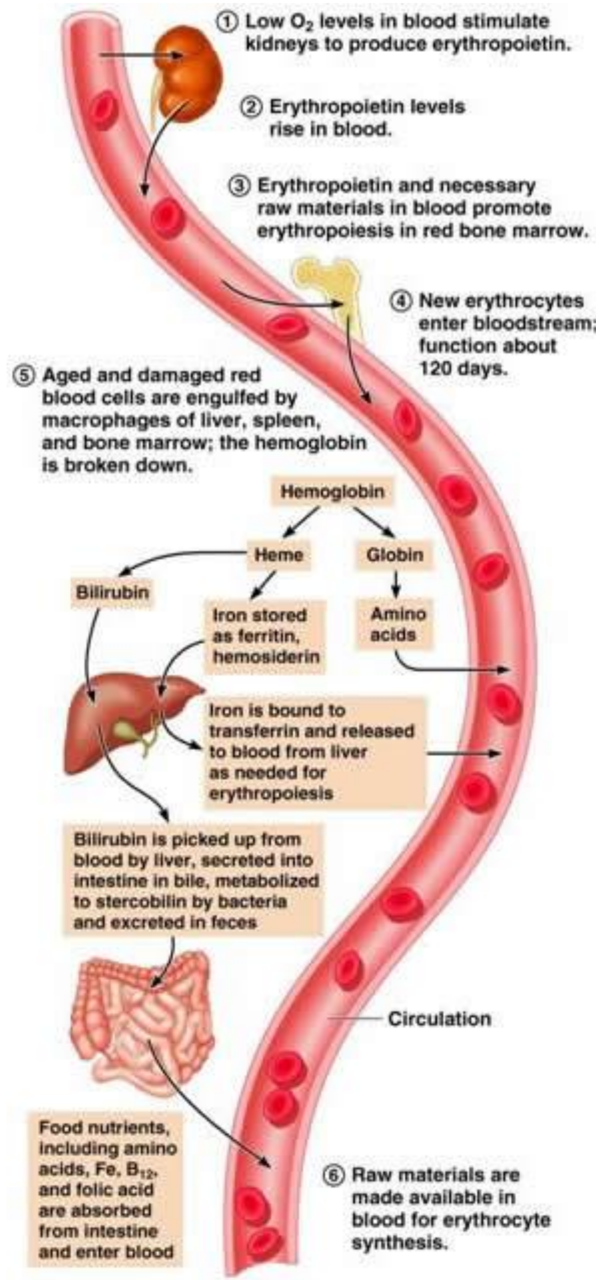
Red Blood Cells

Hemoglobin from the decomposed red blood cells is converted into heme and globin.

Heme is decomposed into iron, which is stored or recycled, and biliverdin and bilirubin, which are excreted in bile.

Fate of RBCs

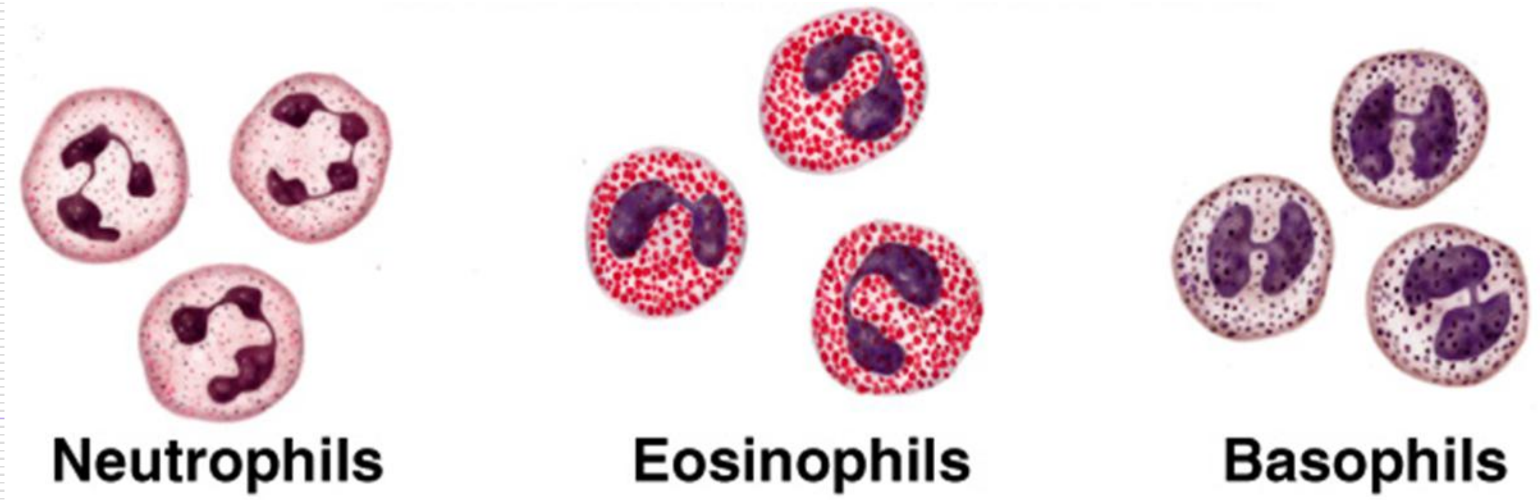

RBCs
Heme
Globin
iron
New RBCs
Bilirubin
Biliverdin
Bile
Amino Acids



① Low O_2 levels in blood stimulate kidneys to produce erythropoietin.
② Erythropoietin levels rise in blood.
③ Erythropoietin and necessary raw materials in blood promote erythropoiesis in red bone marrow.
④ New erythrocytes enter bloodstream; function about 120 days.
⑤ Aged and damaged red blood cells are engulfed by macrophages of liver, spleen, and bone marrow; the hemoglobin is broken down.
Hemoglobin
Heme
Globin
Bilirubin
Iron stored as ferritin, hemosiderin
Amino acids
Iron is bound to transferrin and released to blood from liver as needed for erythropoiesis
Bilirubin is picked up from blood by liver, secreted into intestine in bile, metabolized to stercobilin by bacteria and excreted in feces
Circulation
Food nutrients, including amino acids, Fe, B_{12}, and folic acid are absorbed from intestine and enter blood
⑥ Raw materials are made available in blood for erythrocyte synthesis.

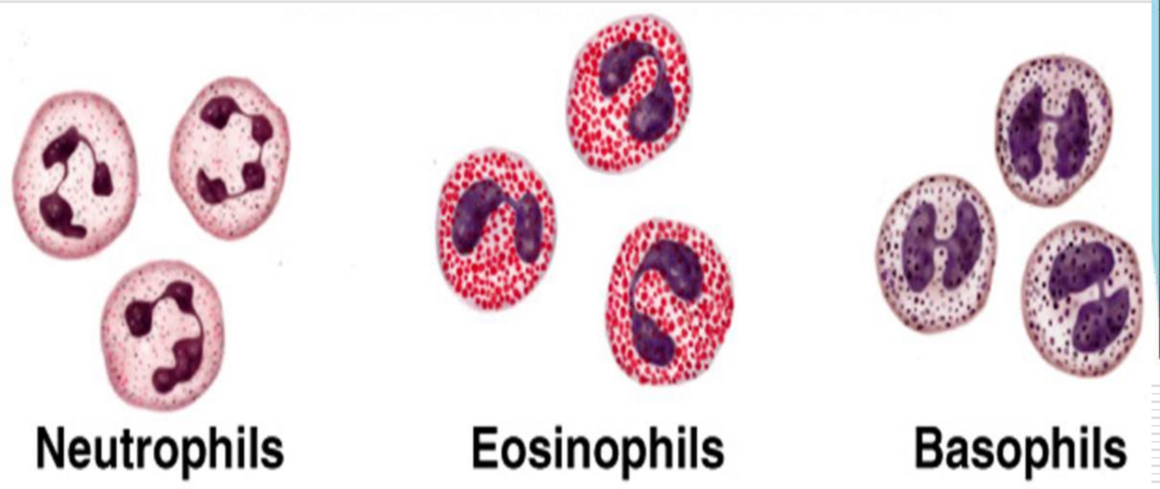
Leukocytes

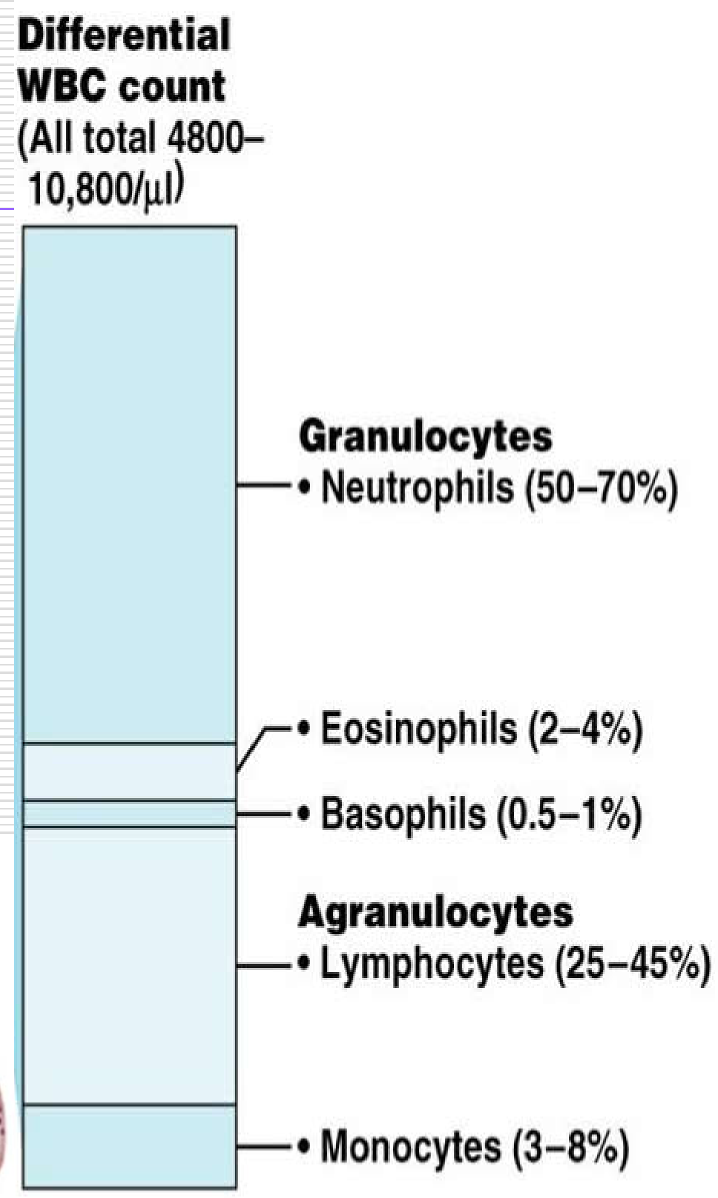
- Complete cells with nucleus & mitochondria
- Make up less than 1% of total blood volume
- Important for defense against disease.



Granulocytes

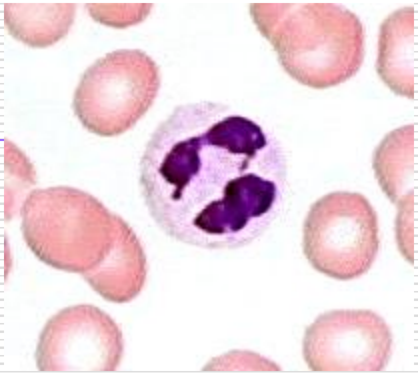
- Main group of leukocytes
- Large cells with lobed nuclei.
- Cytoplasm contains visibly staining granules.
- All are phagocytic.

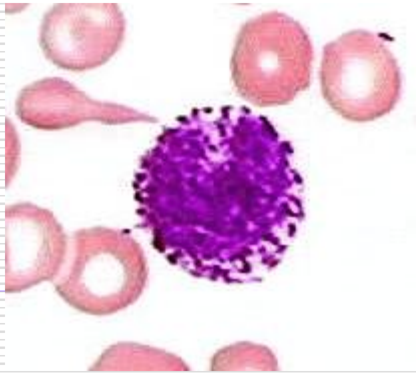




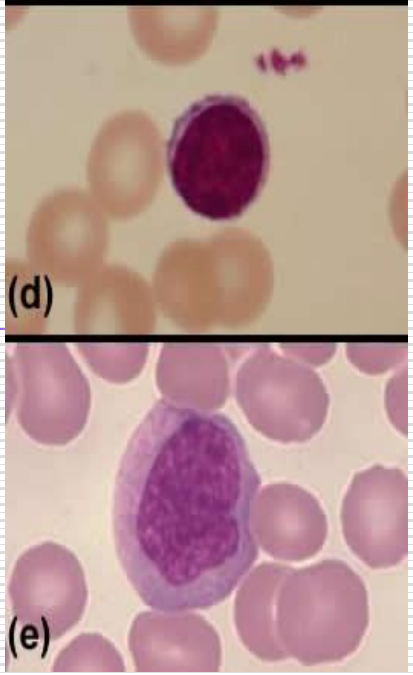
Granulocytes

- **Neutrophils**
  - The most numerous type of leukocyte.
  - They are chemically attracted to sites of inflammation (chemotaxis)
  - They are active phagocytes.
- b. **Eosinophils**
  - relatively few
  - attack parasitic worms.
- c. **Basophils**
  - the least numerous leukocyte
  - Release histamine to promote inflammation.

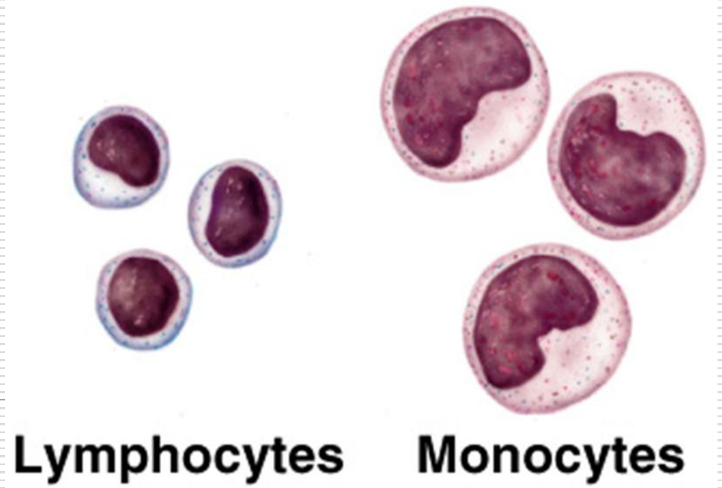




Agranulocytes



- The main group of lymphocytes without staining granules
- **Lymphocytes**
  - **T lymphocytes**
    - directly attack viral-infected and tumor cells
  - **B lymphocytes**
    - produce antibody cells.
- **Monocytes**
  - become macrophages
  - activate T lymphocytes.



Platelets (thrombocytes)

- The smallest of formed elements
- lack nucleus
- Are fragments of megakaryocytes; amoeboid
- Constitute most of mass of blood clots
- Release serotonin to vasoconstrict & reduce blood flow to clot area
- Secrete growth factors to maintain integrity of blood vessel wall
- Survive 5-9 days

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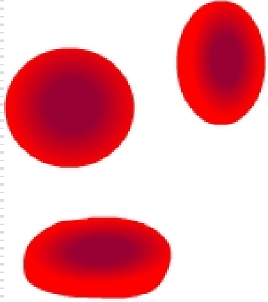
Platelets

Haemostasis (stop bleeding) Blood Clotting



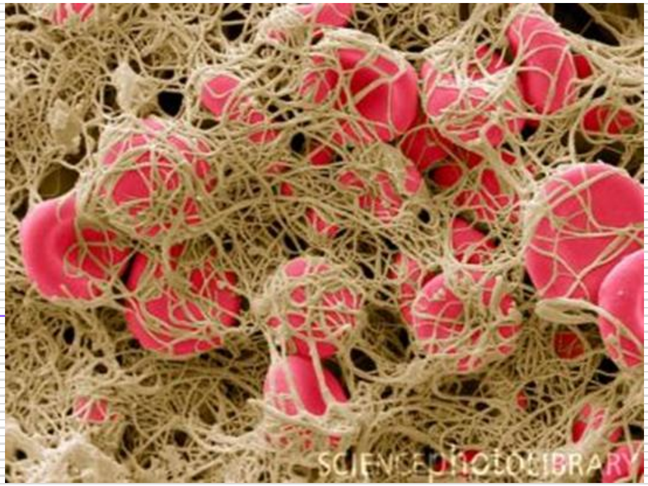
1
Blood vessel spasm (constriction)

2
Platelets plug formation

3
Clotting cascade activated

CLOT
Platelets
+RBCS
+
Fibrin

Blood clotting



Prothrombin
Inactive enzyme

→

Thrombin
Active enzyme

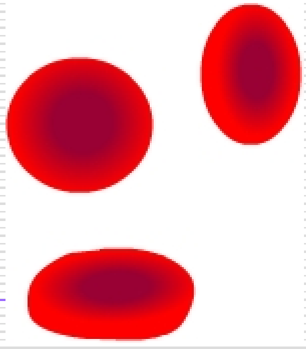
Fibrinogen
Soluble plasma protein

→

Fibrin threads
Insoluble
Fibrous protein

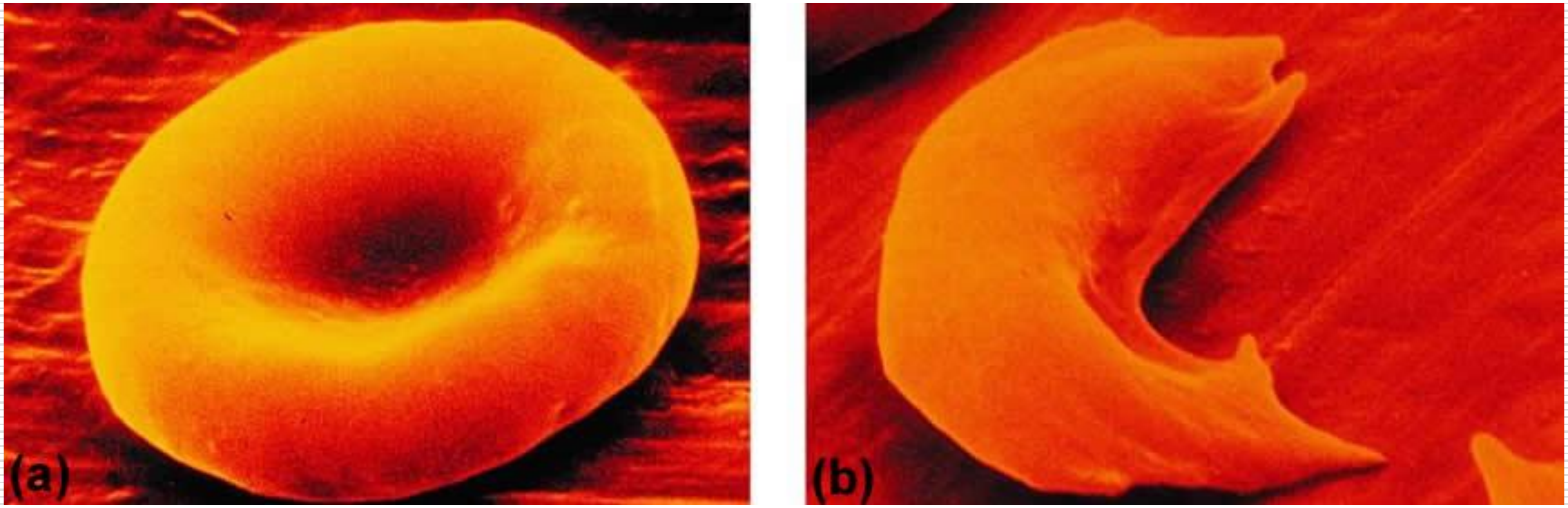
CLOT
Platelets
+RBCS
+
Fibrin

Blood diseases

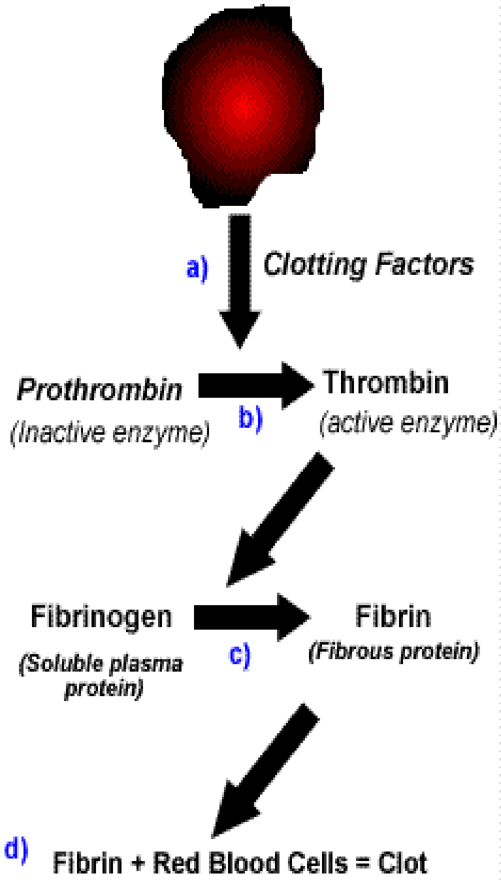


- **Anemia**
  - **Decrease** in the number of RBCs or hemoglobin content (due to bleeding or Fe deficiency) **symptom**
- **polycythemia**
  - **abnormal increase** in the number of RBCs in the blood (due to excess production of these cells by the bone marrow).
- **Leucopenia**
  - **Decrease** in number of WBCs
- **Leucokemia**
  - **Abnormal increase** in the number of WBCs (due to bone marrow tumor)

Sickle Cell



Clotting is the mechanism that prevents blood loss from broken blood vessels.



- Mechanism
  - **a)** Platelets or damaged cells release a group of proteins called clotting factors. These clotting factors are released into the plasma a wound site.
  - **b)** Clotting factors activate the enzyme **Thrombin** from its inactive form prothrombin
  - **c)** Thrombin turns the soluble plasma protein **fibrinogen** into its insoluble fibrous form **Fibrin.**
  - **d)** Fibrin binds together platelets and blood cells to form a solid 'plug' for the4 wound. This plug is called a clot.

TABLE 17.2 Summary of Formed Elements of the Blood

CELL TYPE	ILLUSTRATION	DESCRIPTION*	CELLS/μl (mm³) OF BLOOD	DURATION OF DEVELOPMENT (D) AND LIFE SPAN (LS)	FUNCTION
Erythrocytes (red blood cells, RBCs)		Biconcave, anucleate disc; salmon-colored; diameter 7–8 μm	4–6 million	D: about 15 days LS: 100–120 days	Transport oxygen and carbon dioxide
Leukocytes (white blood cells, WBCs)		Spherical, nucleated cells	4800–10,800		
Granulocytes					
▪ Neutrophil		Nucleus multilobed; inconspicuous cytoplasmic granules; diameter 10–12 μm	3000–7000	D: about 14 days LS: 6 hours to a few days	Phagocytize bacteria
▪ Eosinophil		Nucleus bilobed; red cytoplasmic granules; diameter 10–14 μm	100–400	D: about 14 days LS: about 5 days	Kill parasitic worms; destroy antigen-antibody complexes; inactivate some inflammatory chemicals of allergy
▪ Basophil		Nucleus lobed; large purplish-black cytoplasmic granules; diameter 10–14 μm	20–50	D: 1–7 days LS: a few hours to a few days	Release histamine and other mediators of inflammation; contain heparin, an anticoagulant
Agranulocytes					
▪ Lymphocyte		Nucleus spherical or indented; pale blue cytoplasm; diameter 5–17 μm	1500–3000	D: days to weeks LS: hours to years	Mount immune response by direct cell attack or via antibodies
▪ Monocyte		Nucleus U or kidney shaped; gray-blue cytoplasm; diameter 14–24 μm	100–700	D: 2–3 days LS: months	Phagocytosis; develop into macrophages in the tissues
Platelets		Discoid cytoplasmic fragments containing granules; stain deep purple; diameter 2–4 μm	150,000–400,000	D: 4–5 days LS: 5–10 days	Seal small tears in blood vessels; instrumental in blood clotting

*Appearance when stained with Wright's stain.

The Respiratory System

Oxygen Delivery System

Learning Outcomes

- Describe the **primary functions** of the respiratory system,
- Explain how the delicate **respiratory exchange surfaces** are protected from debris, pathogens, and other hazards.
- Identify the **structures that conduct air** to the lungs, and describe their functions.
- Describe the **functional anatomy of alveoli**, and the superficial anatomy of the lungs

Learning Outcomes

- Define and compare the **processes of external respiration and internal respiration**
- Describe the physical principles governing the **movement of air into the lungs** and the **actions of the respiratory muscles**.
- Describe the physical **principles governing the diffusion of gases into and out of the blood**.
- Describe **how oxygen and carbon dioxide are transported in the blood**.

Learning Outcomes

- List the **factors that influence the rate of respiration**.
- Describe the **reflexes that regulate respiration**.
- Give examples of **interactions between the respiratory system and other body systems**

About this Chapter

- Structure and function of the respiratory system
- How gasses are exchanged with blood
- How respiration is regulated

Respiration serves the following functions:

- **Respiratory functions**
  - Supply of O_2 and elimination of Co_2 (Gas Exchnage).
- **Non-respiratory functions**
  - Vocalization (allows humans to speak)
  - The regulation of pH.
  - The maintenance of normal body temperature.
  - Coughing and sneezing

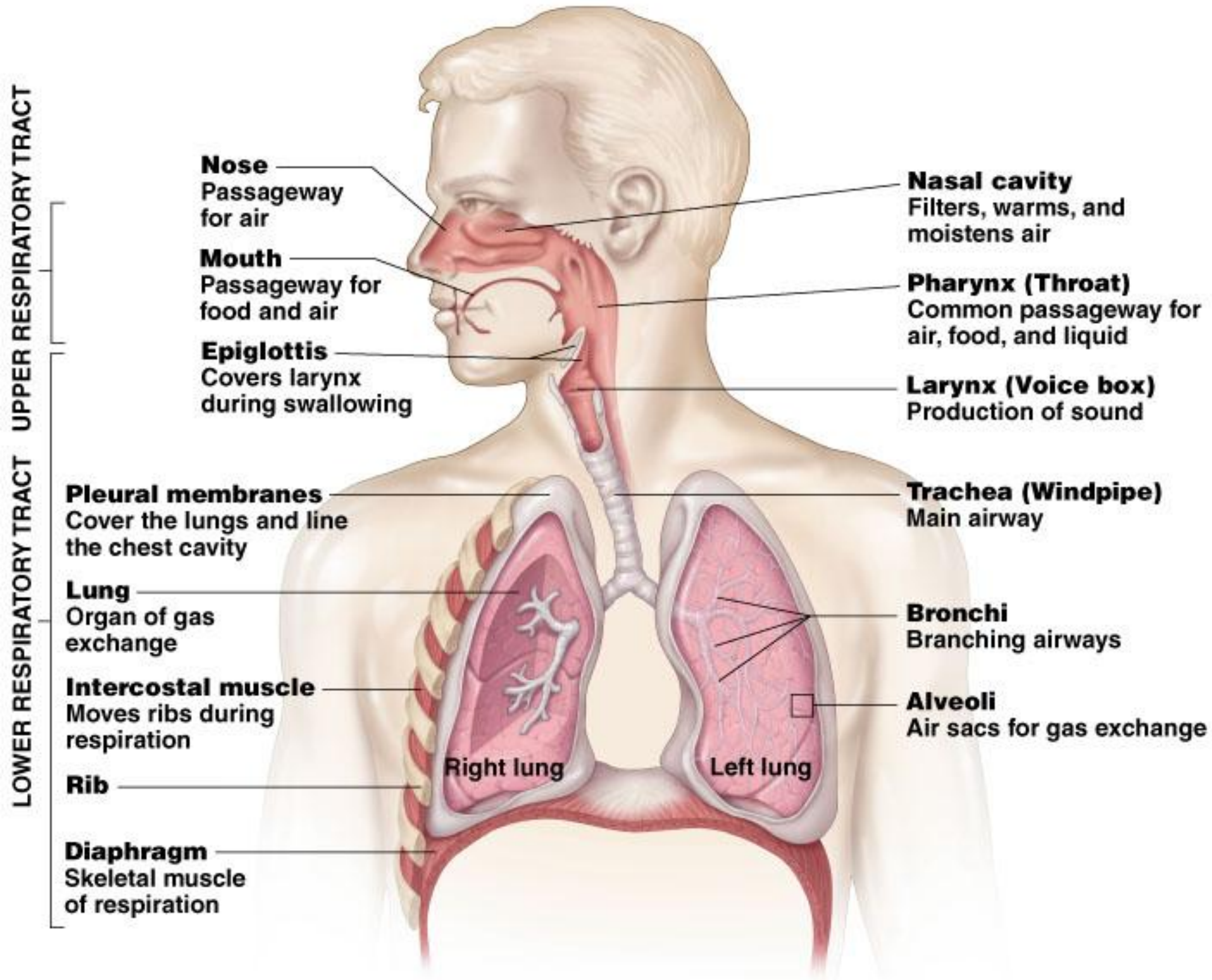
Respiratory System: Overview

- Lungs: exchange surface
  - 75 m^2
  - Thin walled
  - Moist
- Ribs
- Diaphragm & ribs pump air

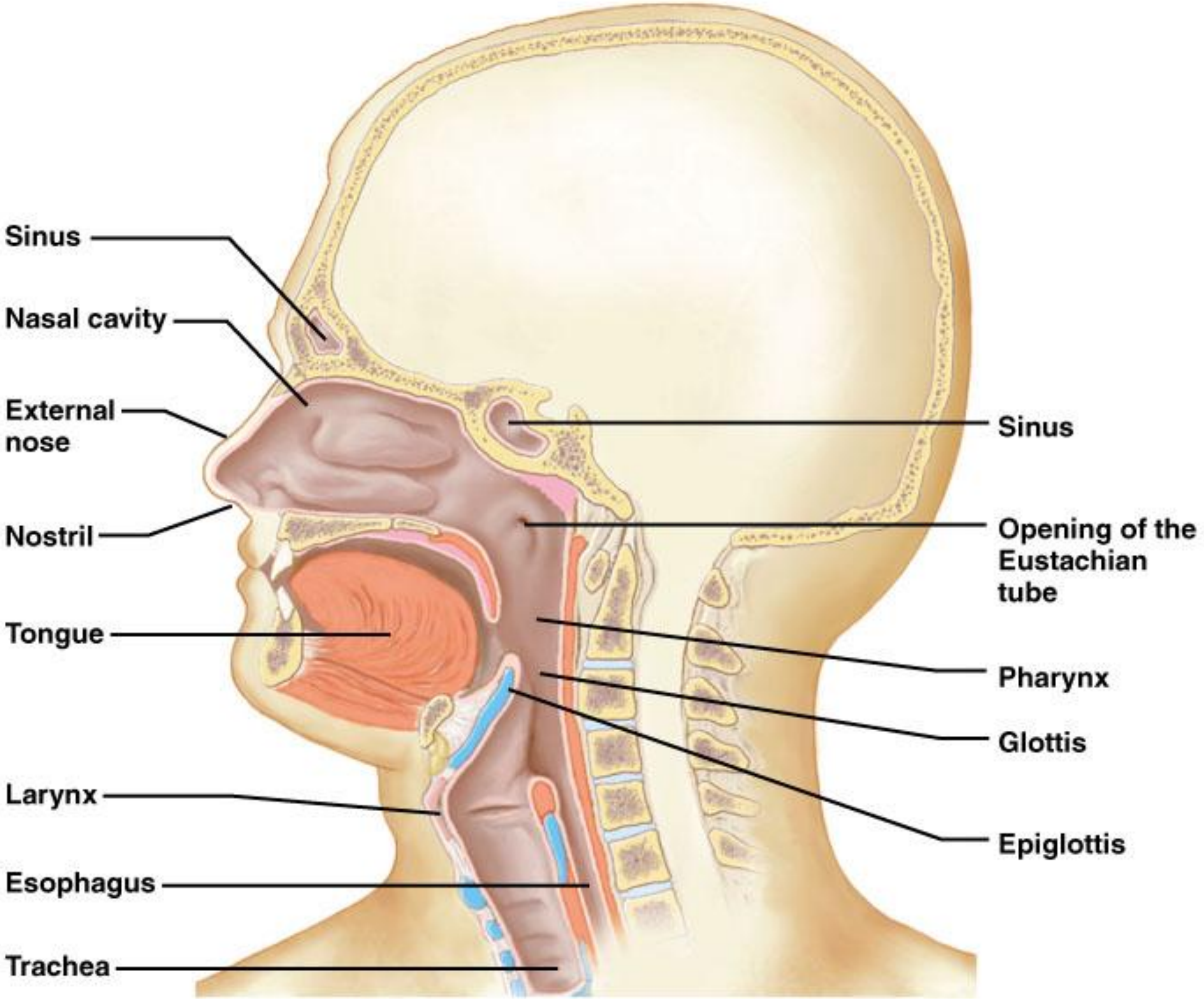
Respiration includes 5 processes:

- **Breathing** (ventilation): air in to and out of lungs
- **External respiration:** The exchange of O2 & CO2 between the blood in the pulmonary capillaries and the air in the lungs.
- **Transport of respiratory gases:** The carriage of O_2 & Co_2 by the blood (RBCs).
- **Internal respiration:** The exchange of O_2 & Co_2 between the blood and tissues.
- **Cellular respiration:** is a process by which cells harvest the energy stored in food. (Glycolysis, the citric acid cycle, and electron transport)

Human Respiratory System



Components of the Upper Respiratory Tract



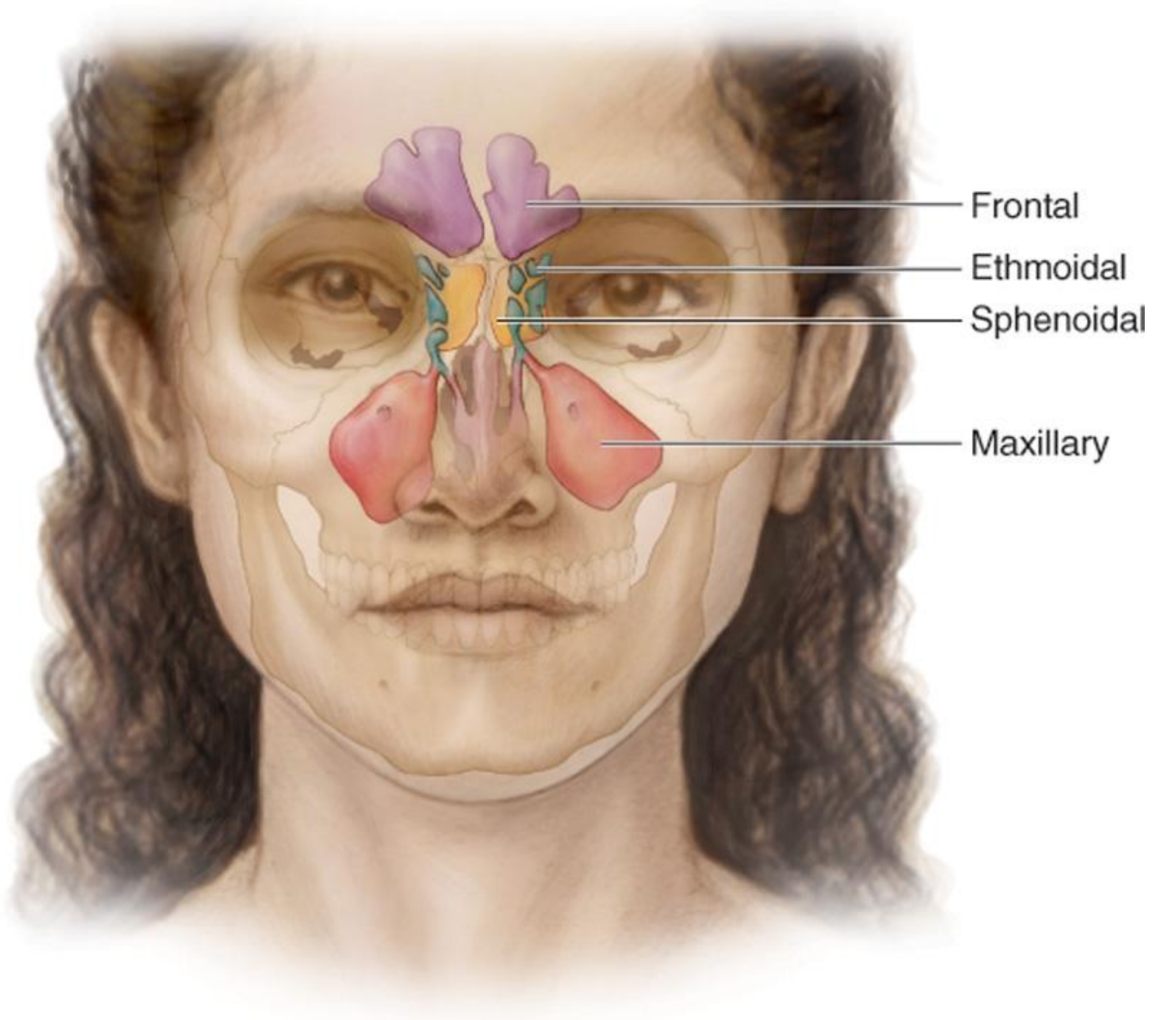
Paranasal sinuses

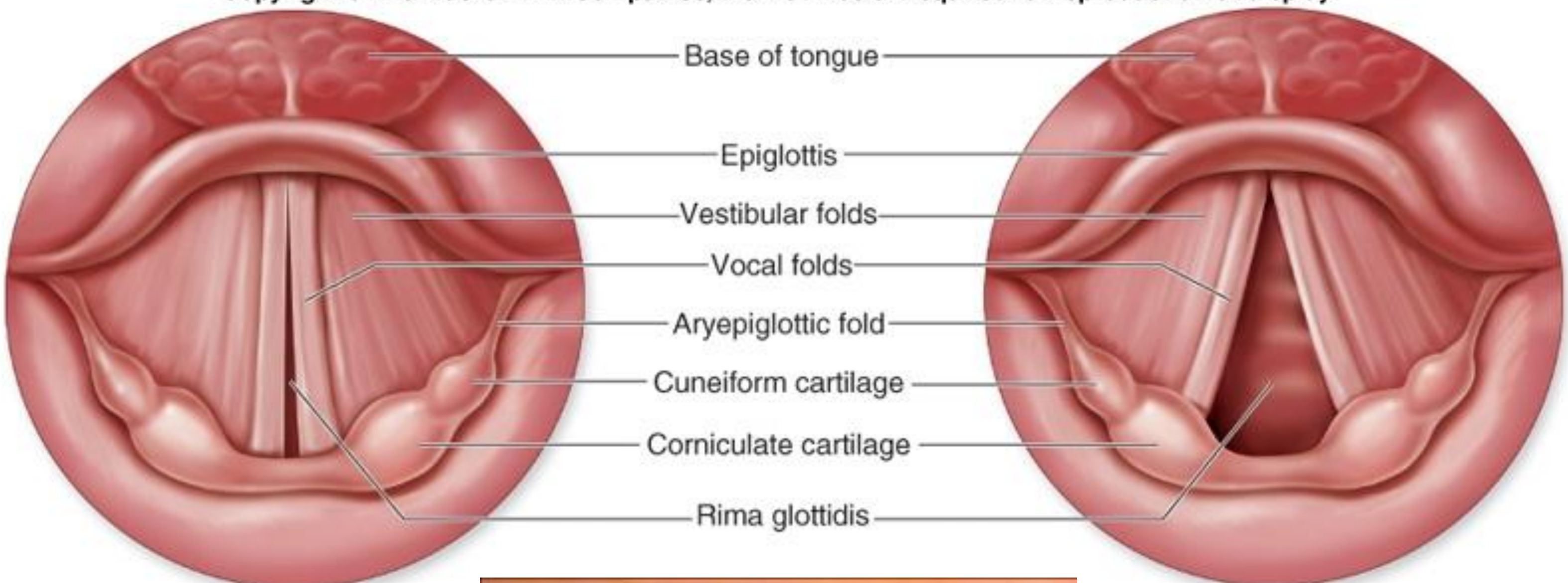
frontal

maxillary

sphenoid

ethmoidal





(b) Laryngoscope view

Upper Respiratory Tract Functions

- Passageway for respiration
- Receptors for smell
- Filters incoming air to filter larger foreign material
- Moistens and warms incoming air
- Resonating chambers for voice

Components of the Lower Respiratory Tract

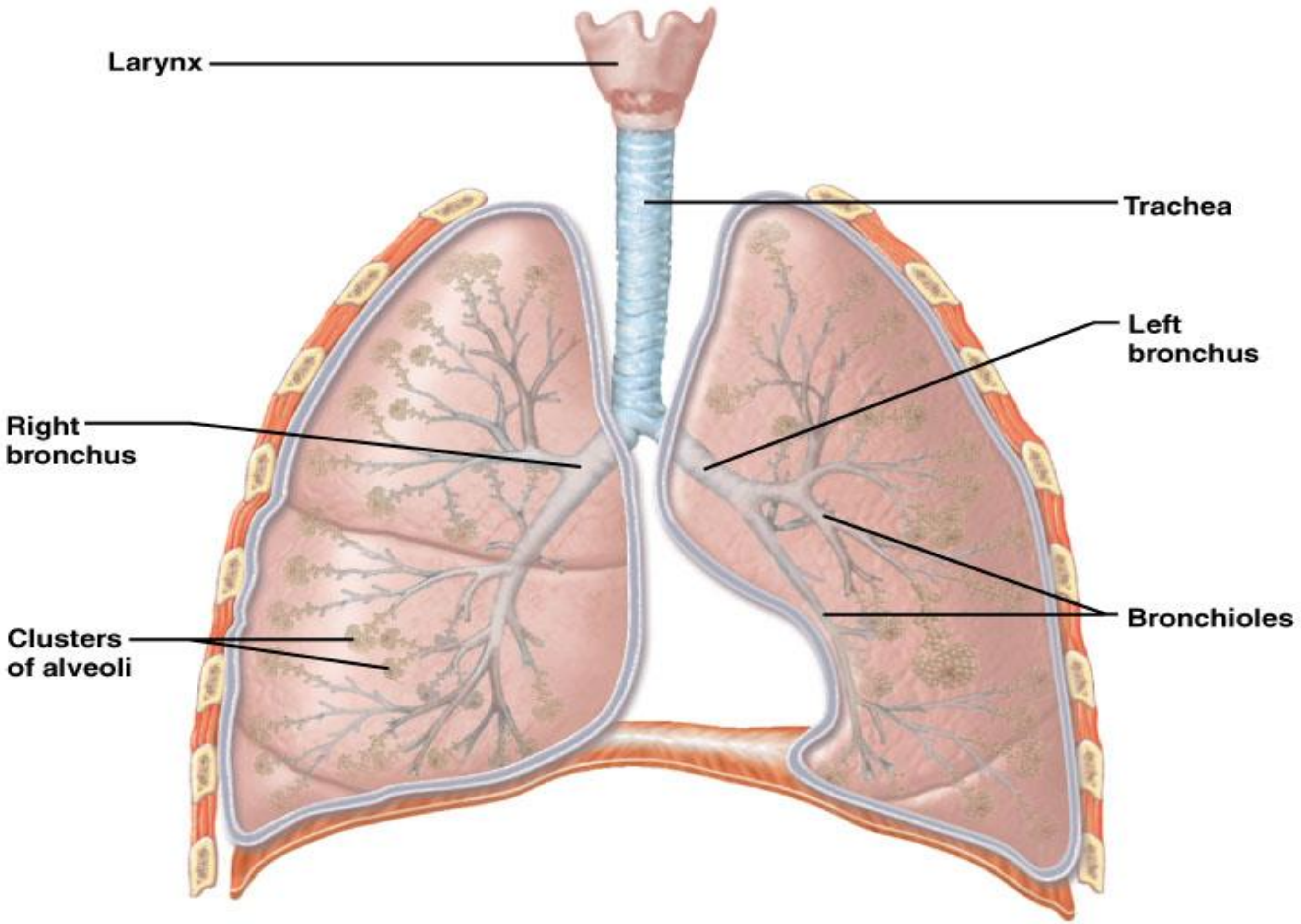
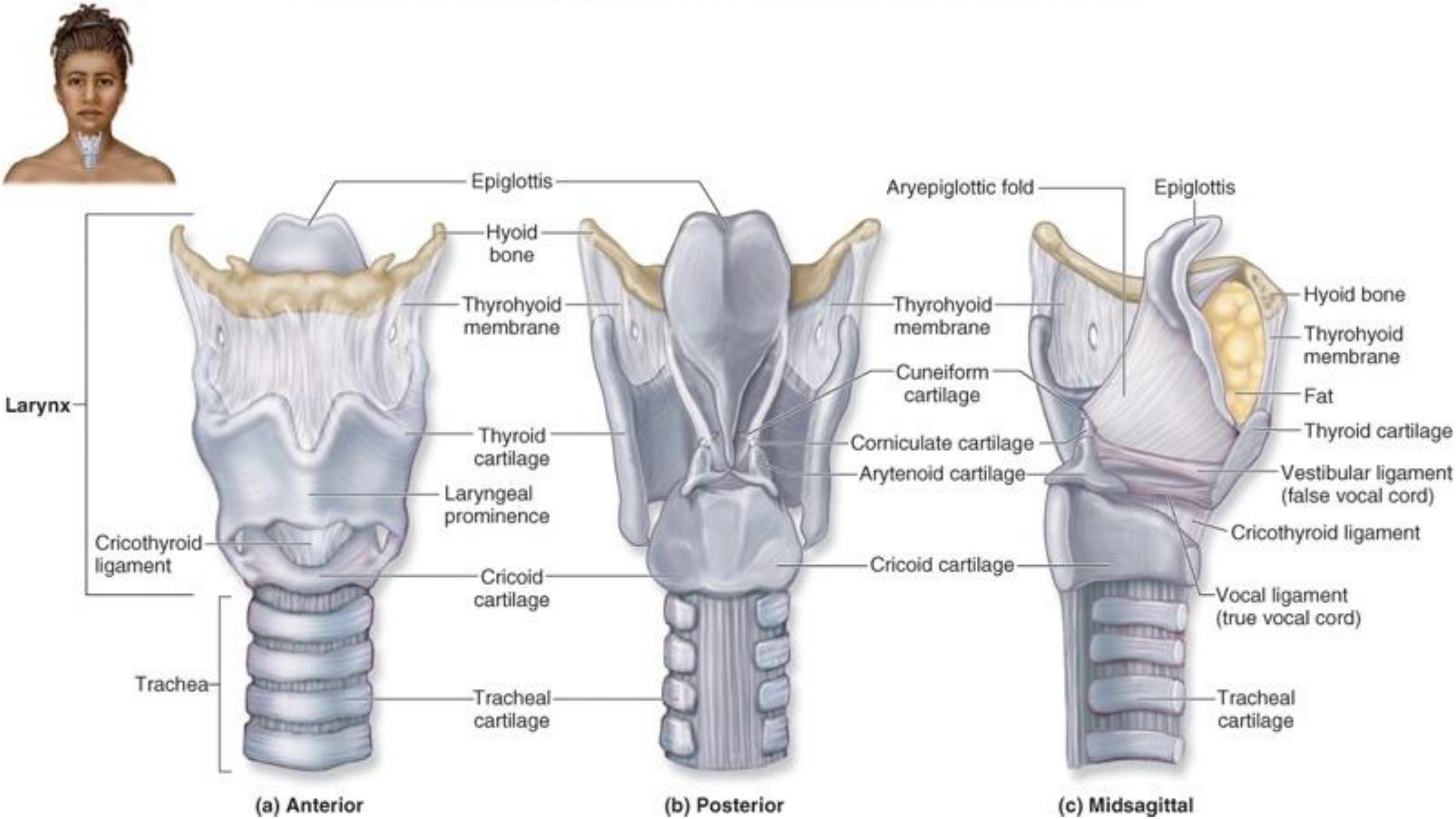
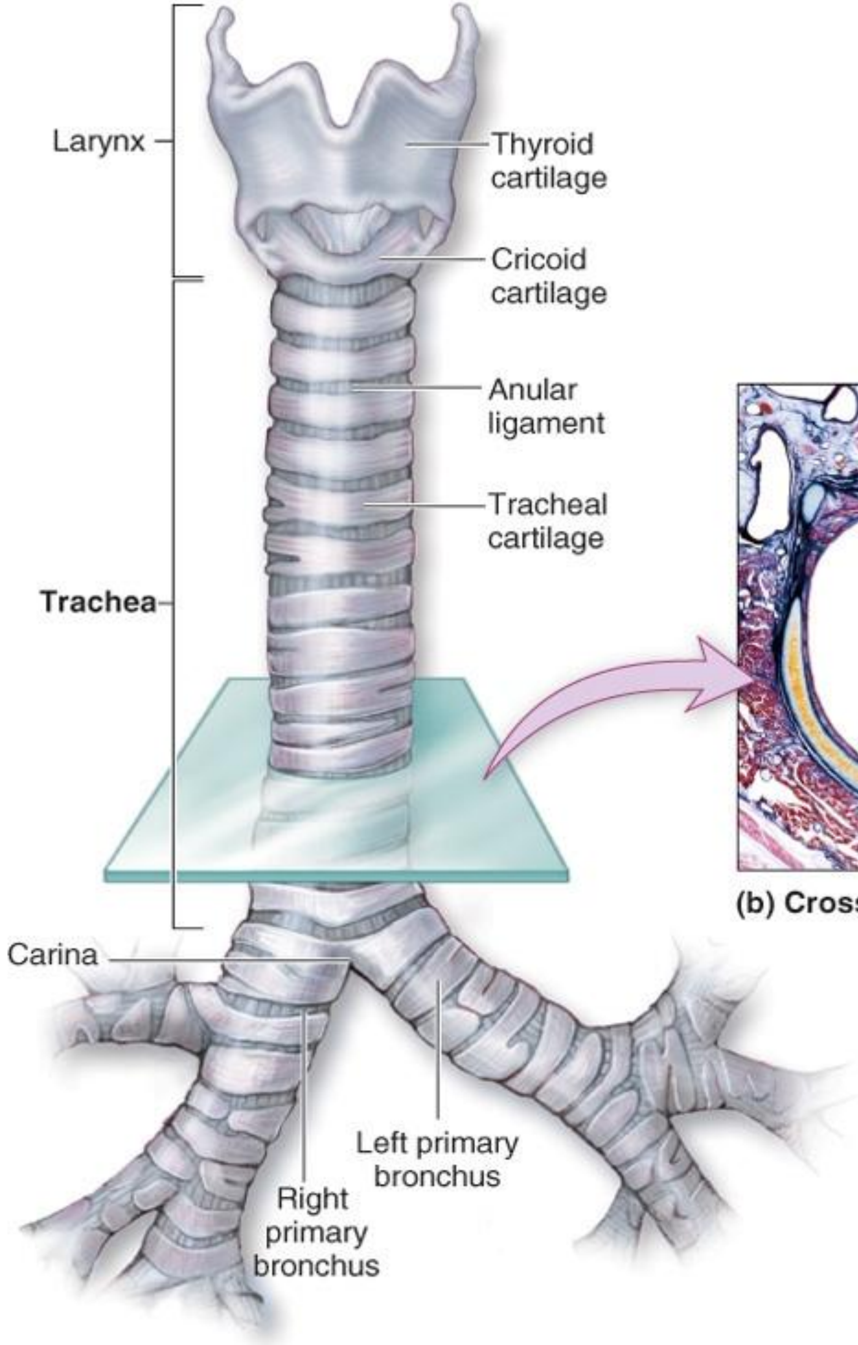
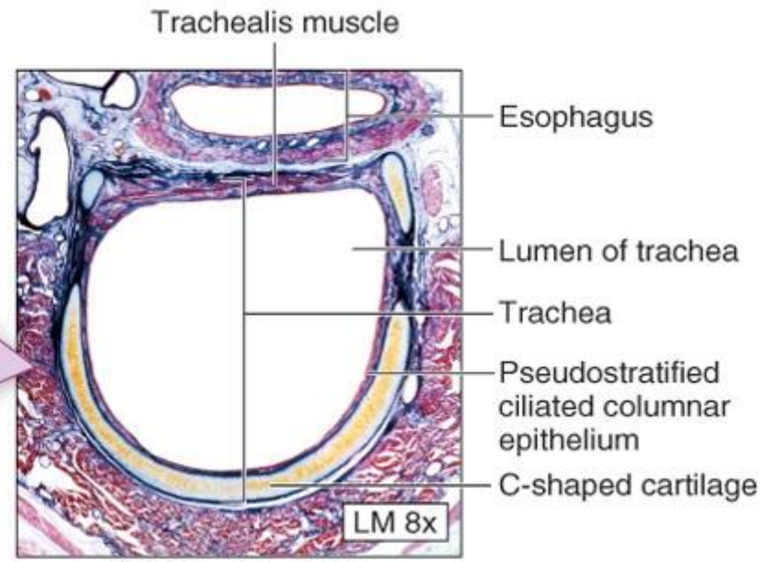


Figure 10.3


Larynx
Trachea
Epiglottis
Hyoid bone
Thyrohyoid membrane
Thyroid cartilage
Laryngeal prominence
Cricothyroid ligament
Cricoid cartilage
Tracheal cartilage
Thyrohyoid membrane
Cuneiform cartilage
Corniculate cartilage
Arytenoid cartilage
Cricoid cartilage
Aryepiglottic fold
Epiglottis
Hyoid bone
Thyrohyoid membrane
Fat
Thyroid cartilage
Vestibular ligament (false vocal cord)
Cricothyroid ligament
Vocal ligament (true vocal cord)
Tracheal cartilage
(a) Anterior
(b) Posterior
(c) Midsagittal



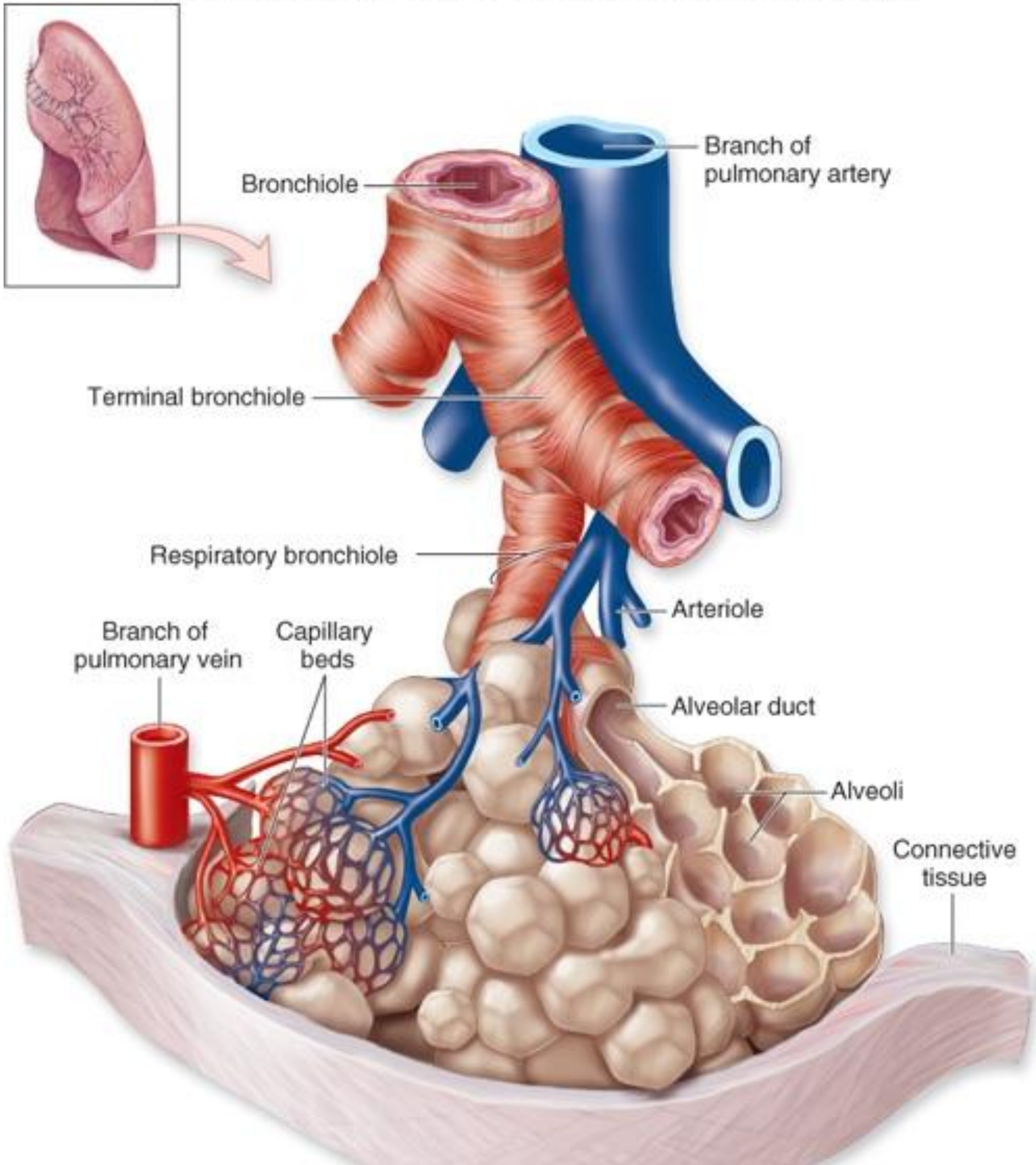
(a) Anterior view



(b) Cross section

Lower Respiratory Tract

- **Functions:**
  - Larynx: maintains an open airway, routes food and air appropriately, assists in sound production
  - Trachea: transports air to and from lungs
  - Bronchi: branch into lungs
  - Lungs: transport air to alveoli for gas exchange



Branch of pulmonary artery
Bronchiole
Terminal bronchiole
Respiratory bronchiole
Arteriole
Branch of pulmonary vein
Capillary beds
Alveolar duct
Alveoli
Connective tissue

(a)

Gas Exchange Between the Blood and Alveoli

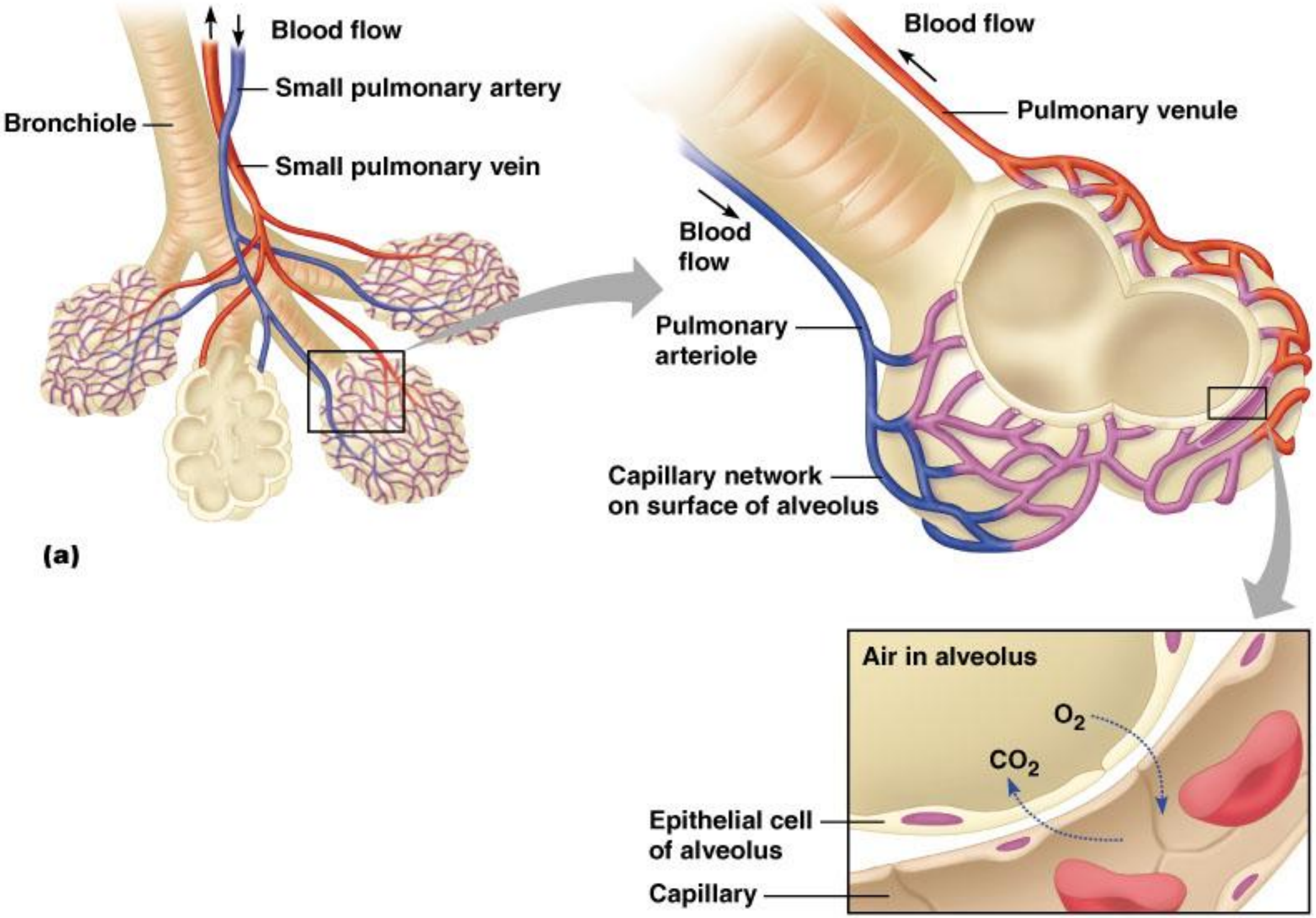
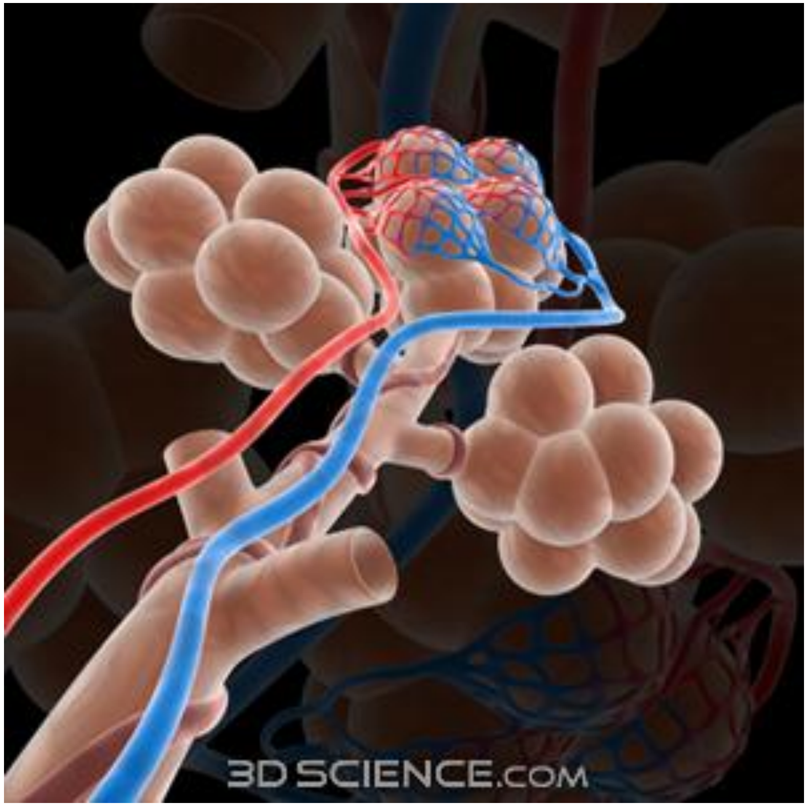
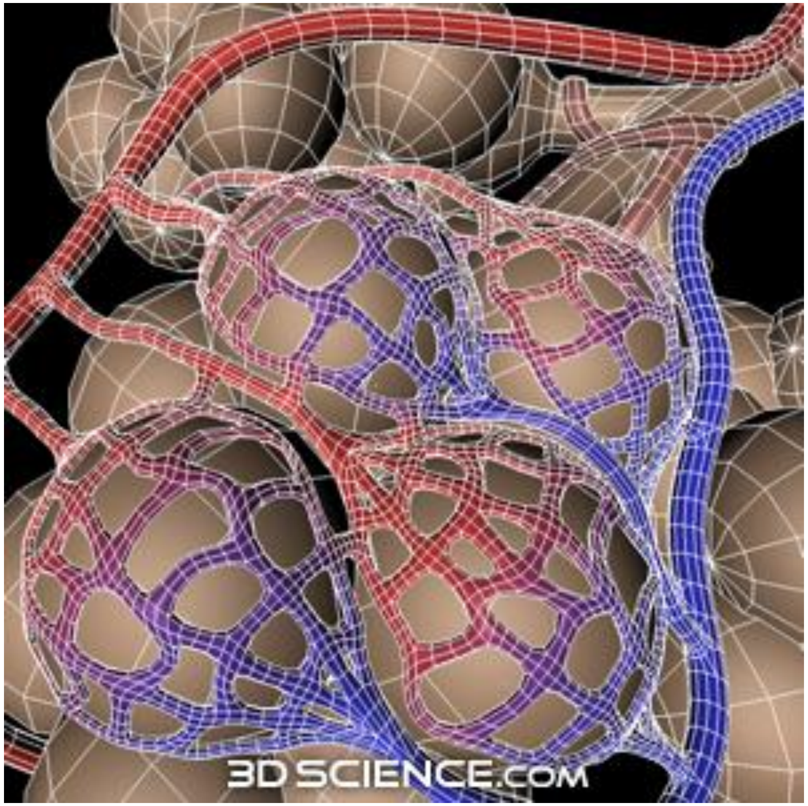
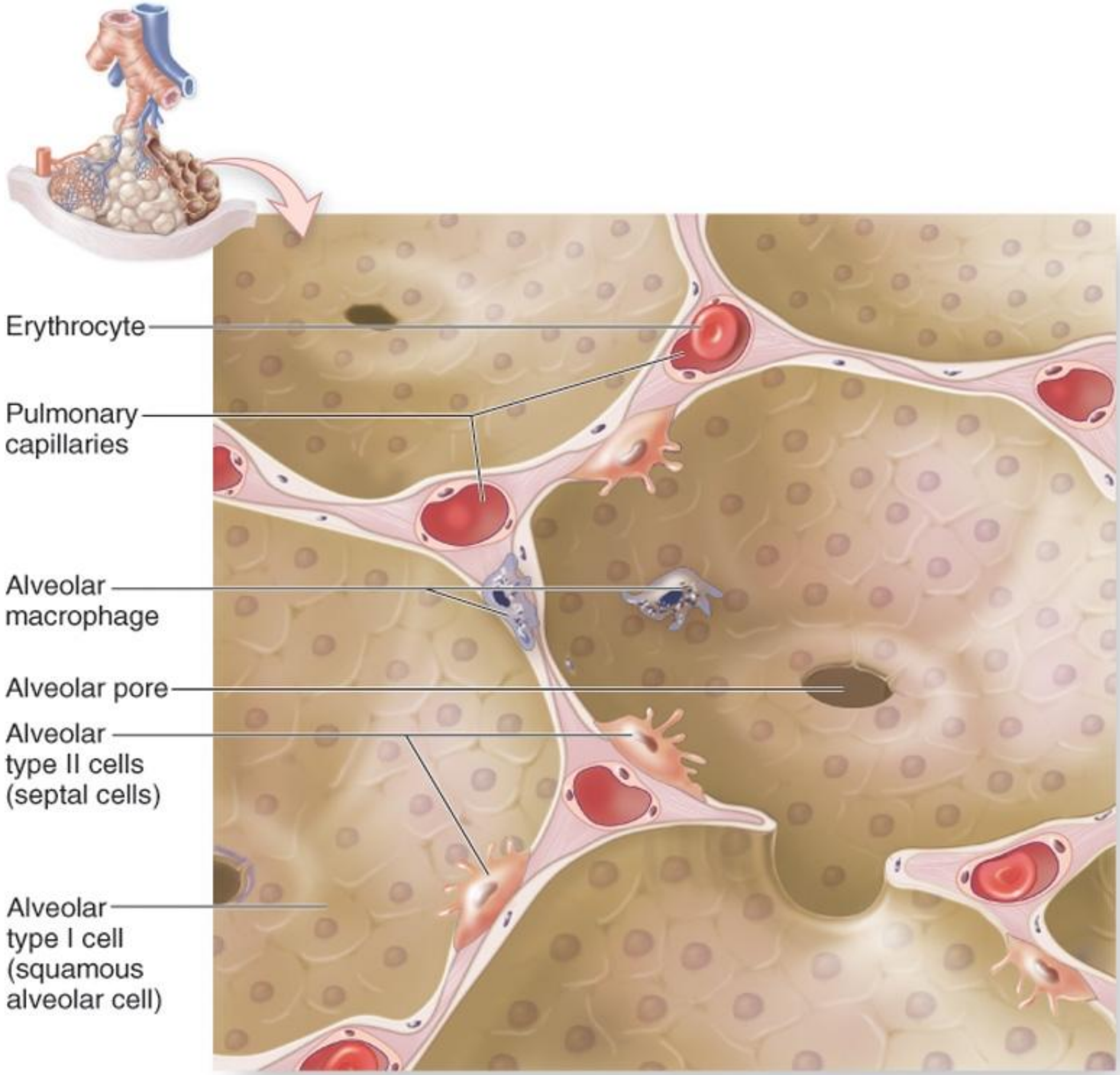


Figure 10.8A

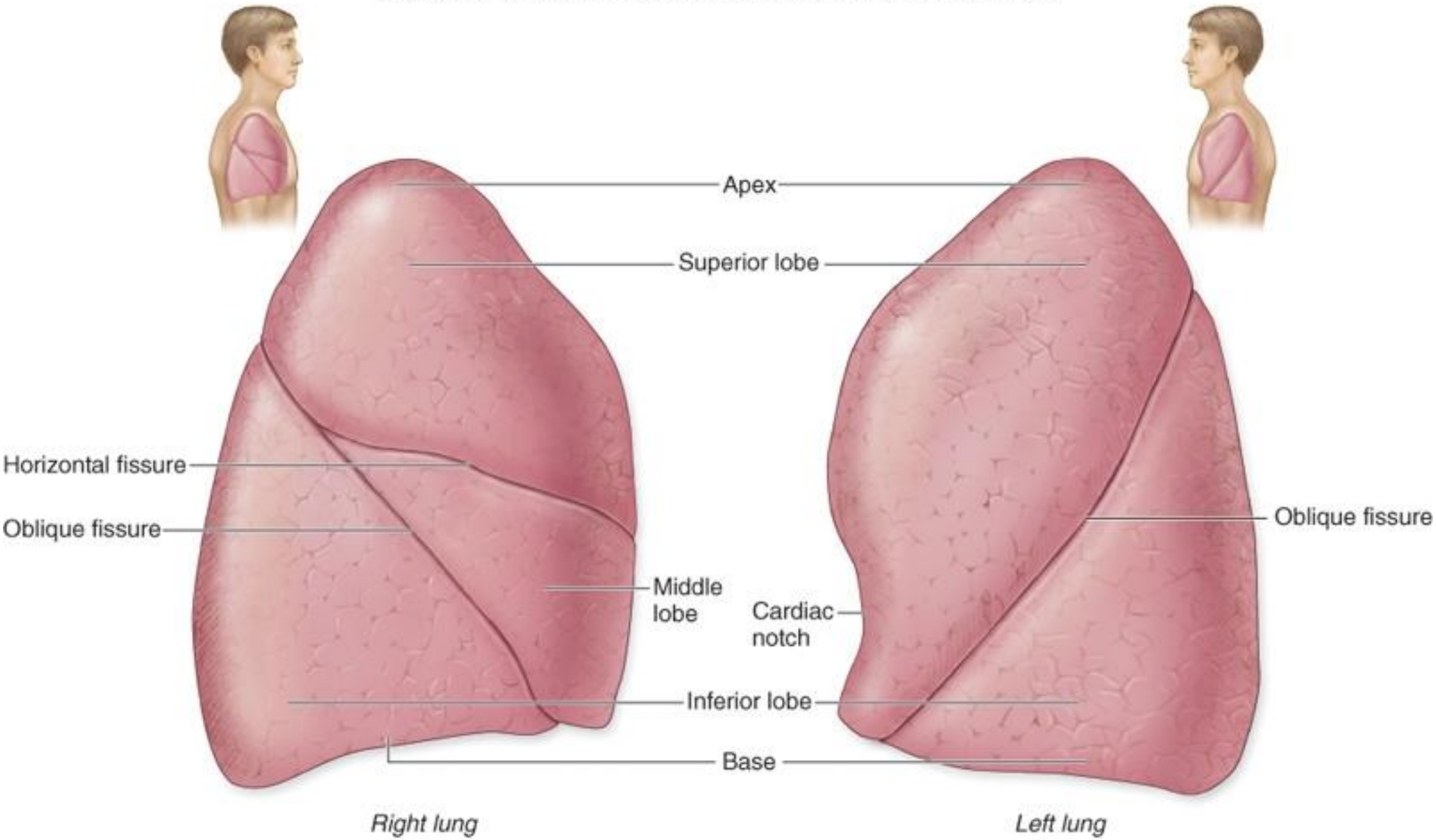
Gas Exchange Between the Blood and Alveoli






Erythrocyte
Pulmonary capillaries
Alveolar macrophage
Alveolar pore
Alveolar type II cells (septal cells)
Alveolar type I cell (squamous alveolar cell)

(a)



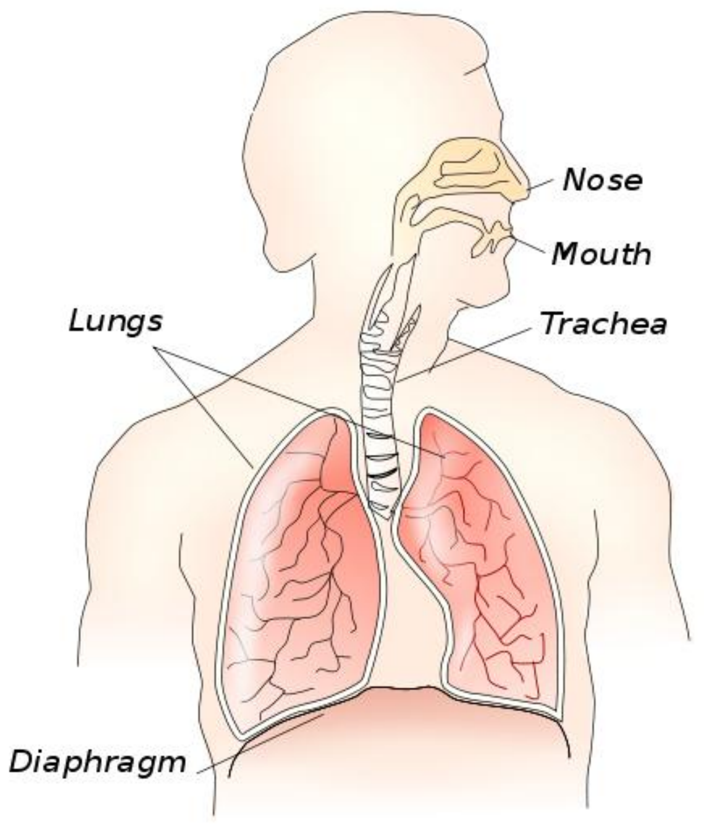
(a) Lateral views

Gas Exchange Between the Blood and Alveoli

- Actual gas exchange takes place Only in the alveoli does .
- There are some 300 million alveoli in two adult lungs.
- These alveoli provide a surface area of some 160 m^2.

The diaphragm

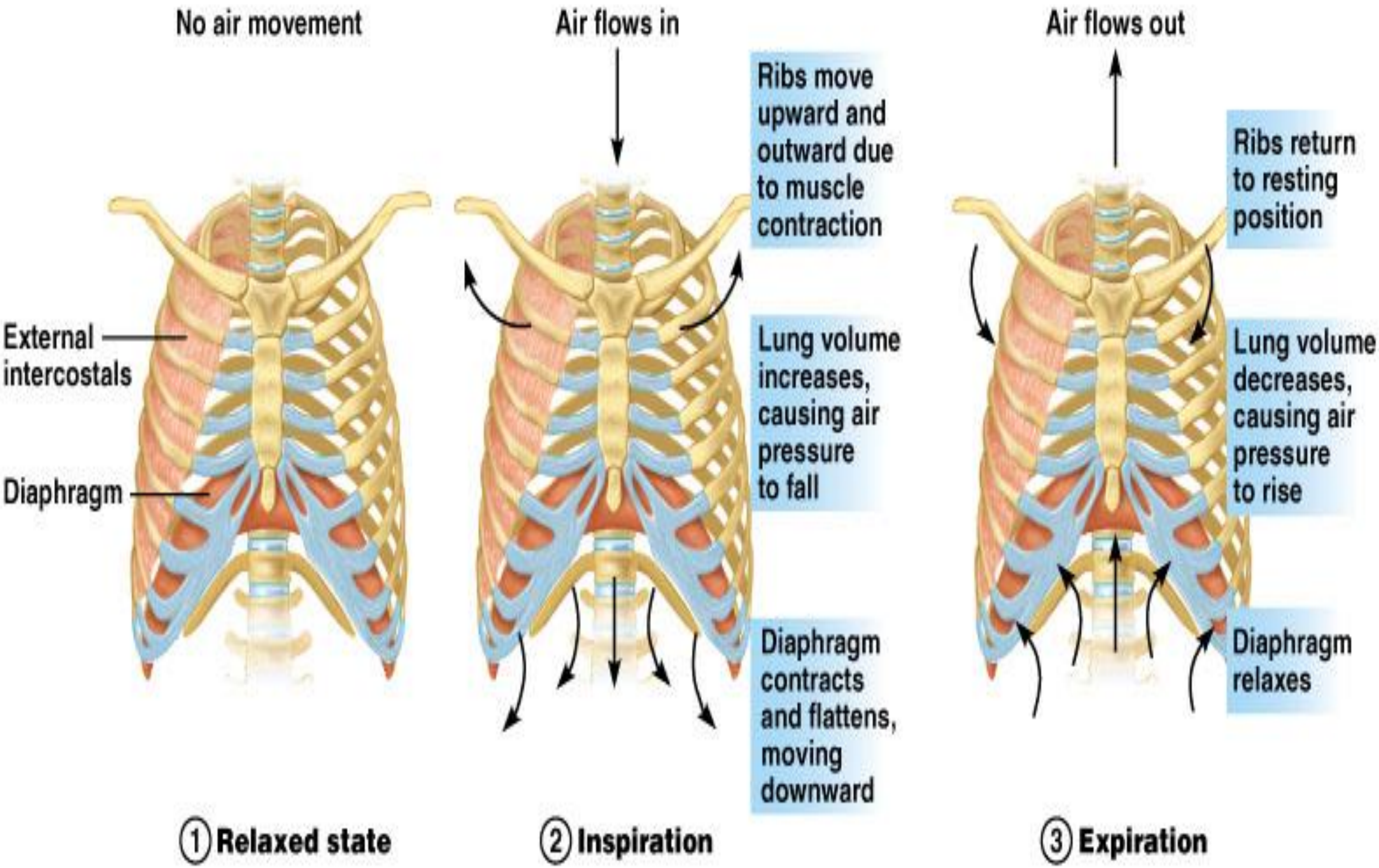
- The diaphragm divides the body cavity into the
  - **Abdominal cavity**
  - **Thoracic cavity**



The diaphragm

- The diaphragm is a sheet of muscles that lies across the bottom of the chest cavity.
- As the diaphragm contracts and relaxes, breathing takes place.
- When the diaphragm contracts, air (O2) is pulled into the lungs.
- When the diaphragm relaxes, air CO2 is pumped out of the lungs.

Respiratory Cycle



Process of Breathing: Pressure Gradient

- Inspiration/Expiration: air in/air out
- Cycle:
  - Relaxed state: diaphragm and intercostal muscles relaxed
  - Inspiration: diaphragm contracts, pulling muscle down, intercostal muscles contract elevating chest wall and expanding volume of chest, lowering pressure in lungs, pulling in air
  - Expiration: muscles relax, diaphragm resumes dome shape, intercostal muscles allow chest to lower resulting in increase of pressure in chest and expulsion of air

Pleural membranes

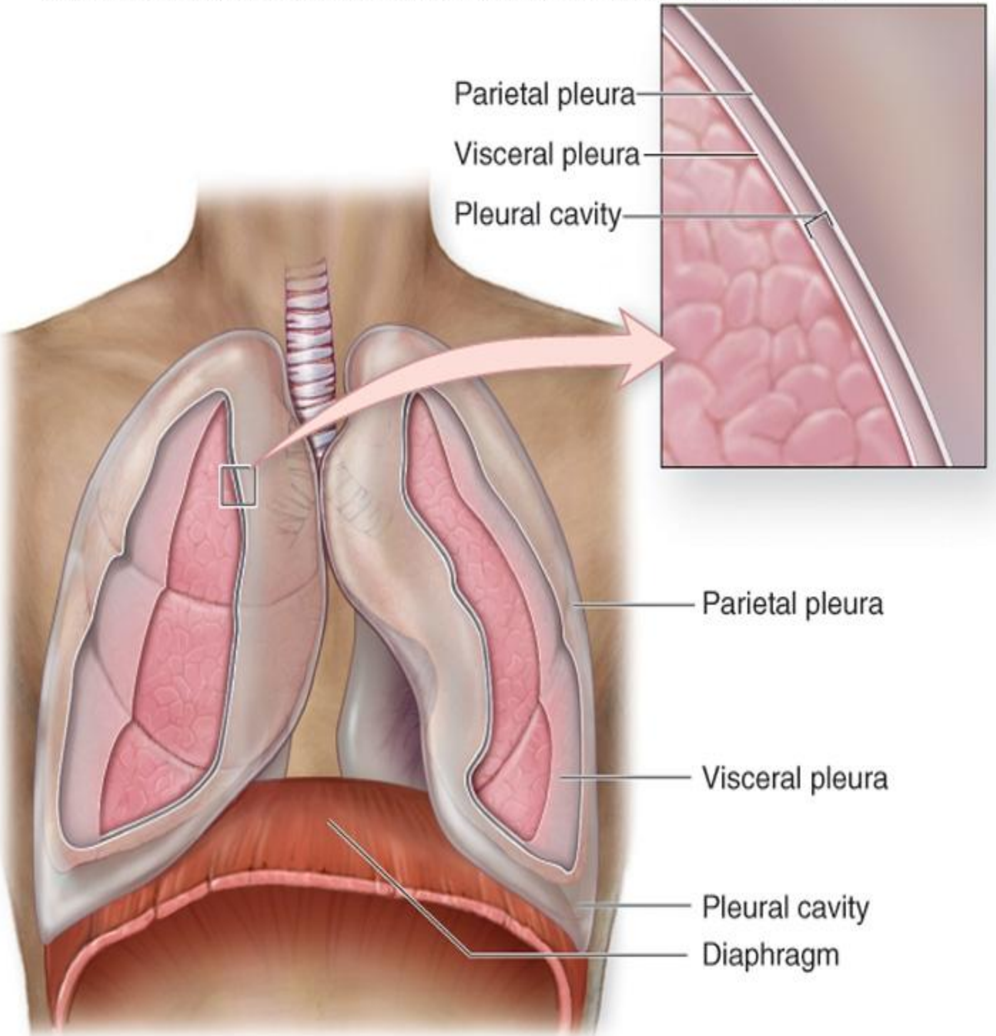
- The inner surface of the thoracic cavity and the outer surface of the lungs are lined with **pleural membranes** which adhere to each other.
- Because of this adhesion, any action that increases the volume of the thoracic cavity causes the lungs to expand, drawing air into them.
- If air is introduced between them, the adhesion is broken and the natural elasticity of the lung causes it to collapse. This can occur from trauma.

Pleural membranes

Parietal pleura

Visceral pleura

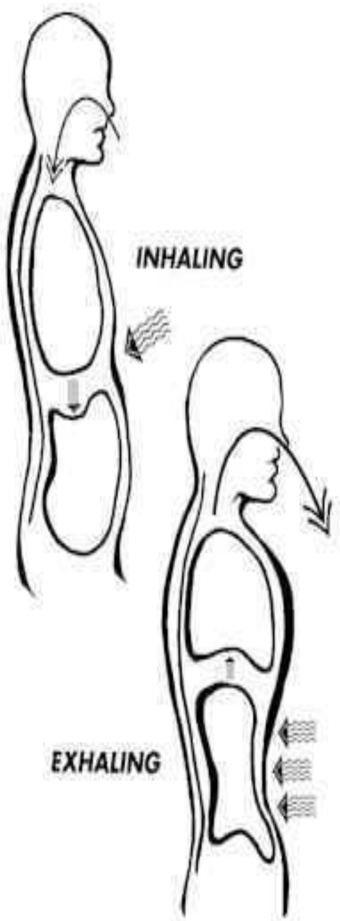
Pleural cavity



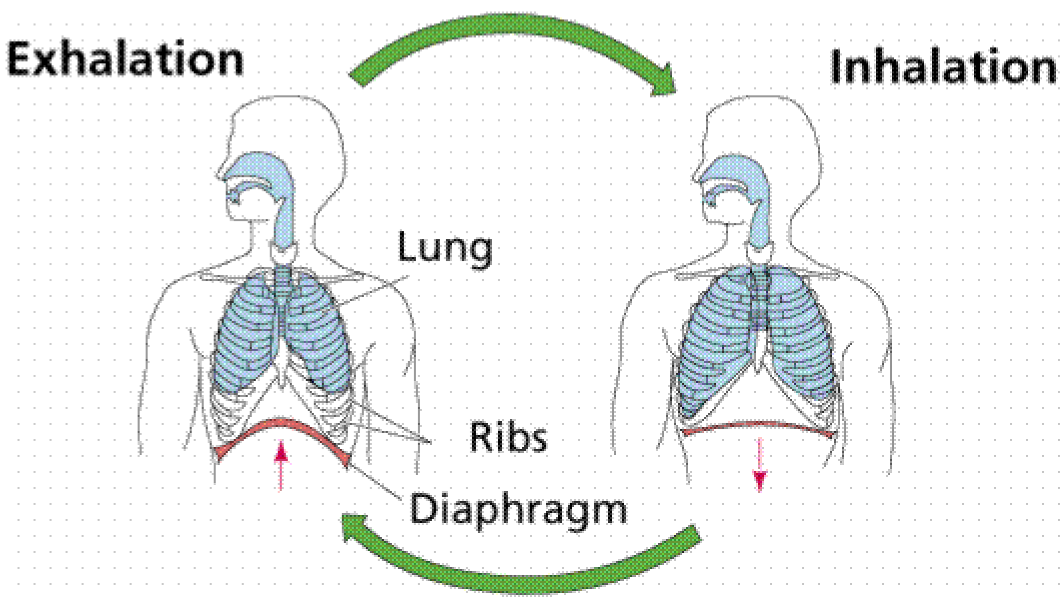
Pleural membranes

- If air is introduced between them, the adhesion is broken and the natural elasticity of the lung causes it to collapse. This can occur from trauma.

Breathing



- At rest, we breath 15-18 times a minute exchanging about 500 ml of air.



Breathing

- In more vigorous expiration,
  - The internal **intercostal muscles** draw the ribs down and inward
  - The wall of the abdomen contracts pushing the stomach and liver upward.
- **Under these conditions**, an average adult male can flush his lungs with about 4 liters of air at each breath. This is called the **vital capacity**. Even with maximum expiration, about 1200 ml of **residual air** remain.

Breathing

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Regulation of Breathing

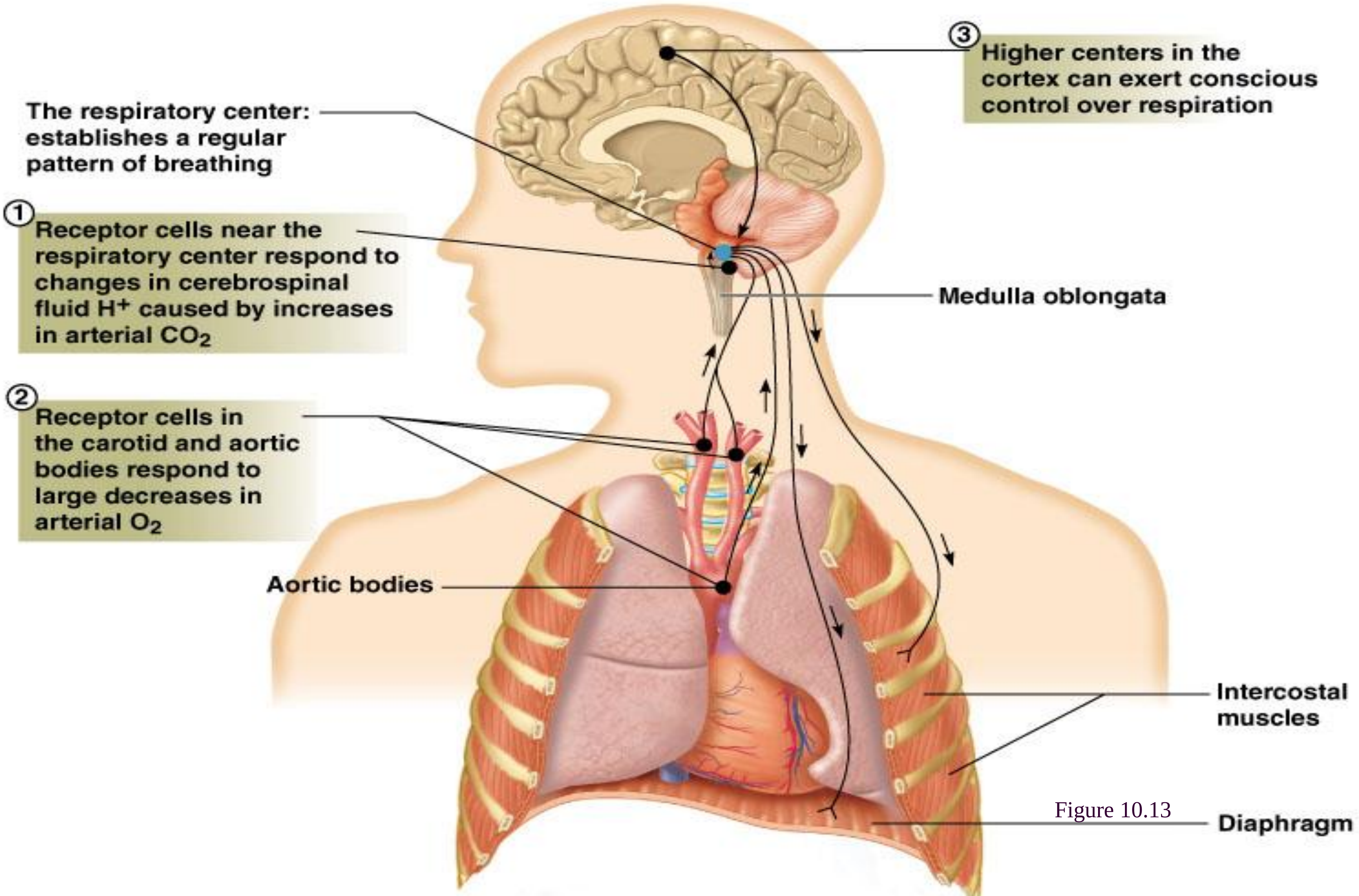
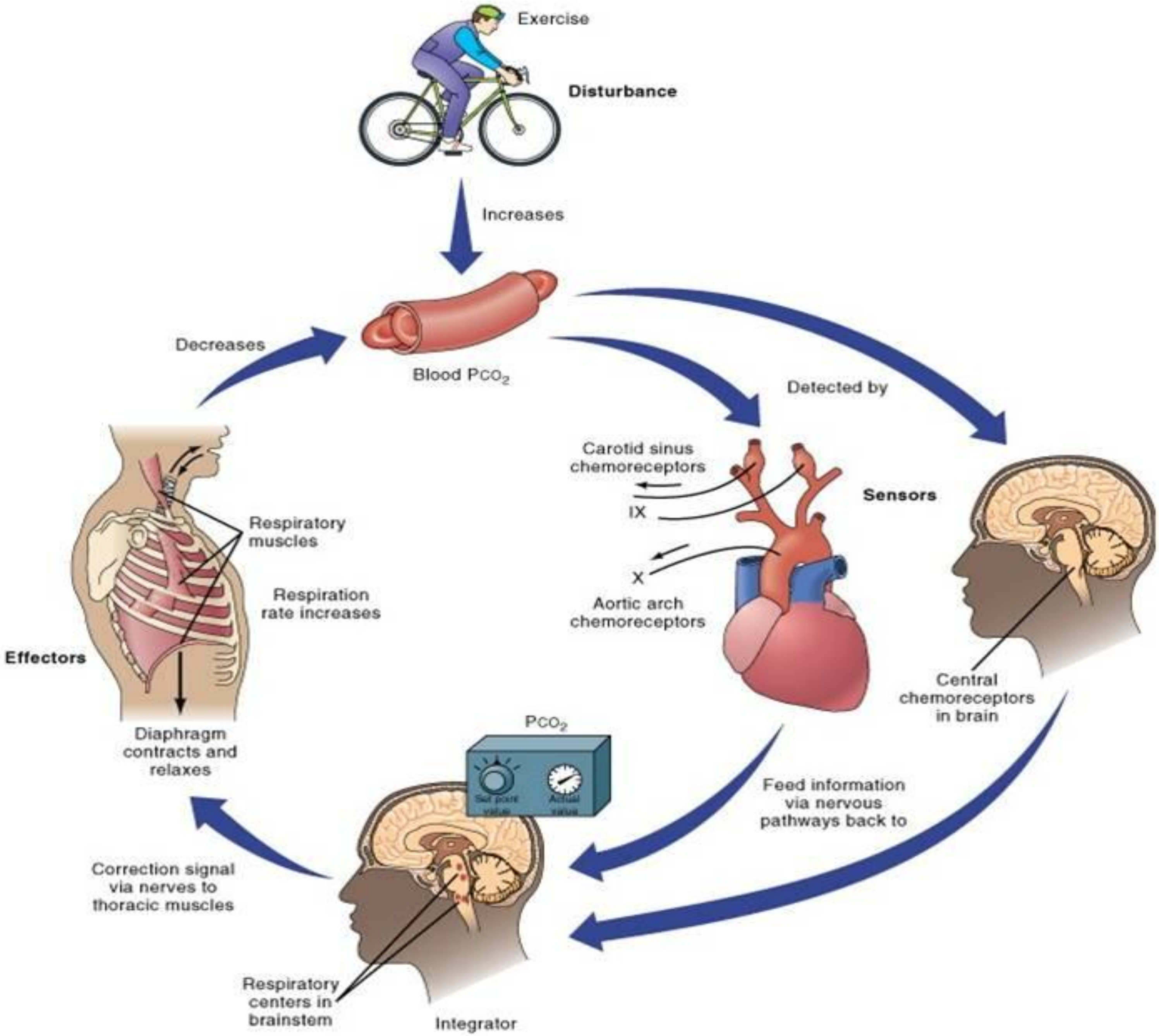


Figure 10.13



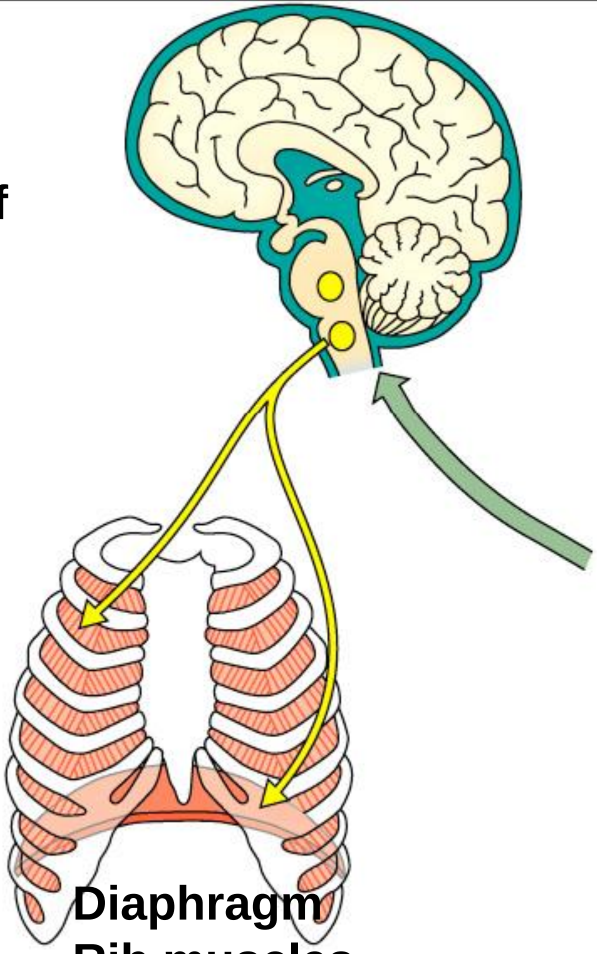
Exercise
Disturbance
Increases
Blood P_{CO_2}
Decreases
Detected by
Carotid sinus chemoreceptors
IX
X
Aortic arch chemoreceptors
Sensors
Central chemoreceptors in brain
Respiratory muscles
Respiration rate increases
Effectors
Diaphragm contracts and relaxes
P_{CO_2}
Set point value
Actual value
Feed information via nervous pathways back to
Correction signal via nerves to thoracic muscles
Respiratory centers in brainstem
Integrator

Regulation of Breathing: Nervous System Involvement

- Carotid and aortic bodies:
  - sensitive to CO_2, pH, and O_2 levels
- Conscious control: resides in higher brain centers; ability to modify breath is limited

Central Control of Breathing

- **The rising concentration of CO_2** — **in blood** not a declining concentration of oxygen — plays the major role in regulating the ventilation of the lungs.
- The concentration of **CO_2** is monitored by cells in the medulla oblongata.
- If the level of **CO_2** rises, the medulla responds by increasing the activity of the motor nerves that control the intercostal muscles and diaphragm.



Nerve signals trigger contraction of muscles
Breathing control centers stimulated by CO2 increase in blood
Diaphragm
Rib muscles

Central Control of Breathing

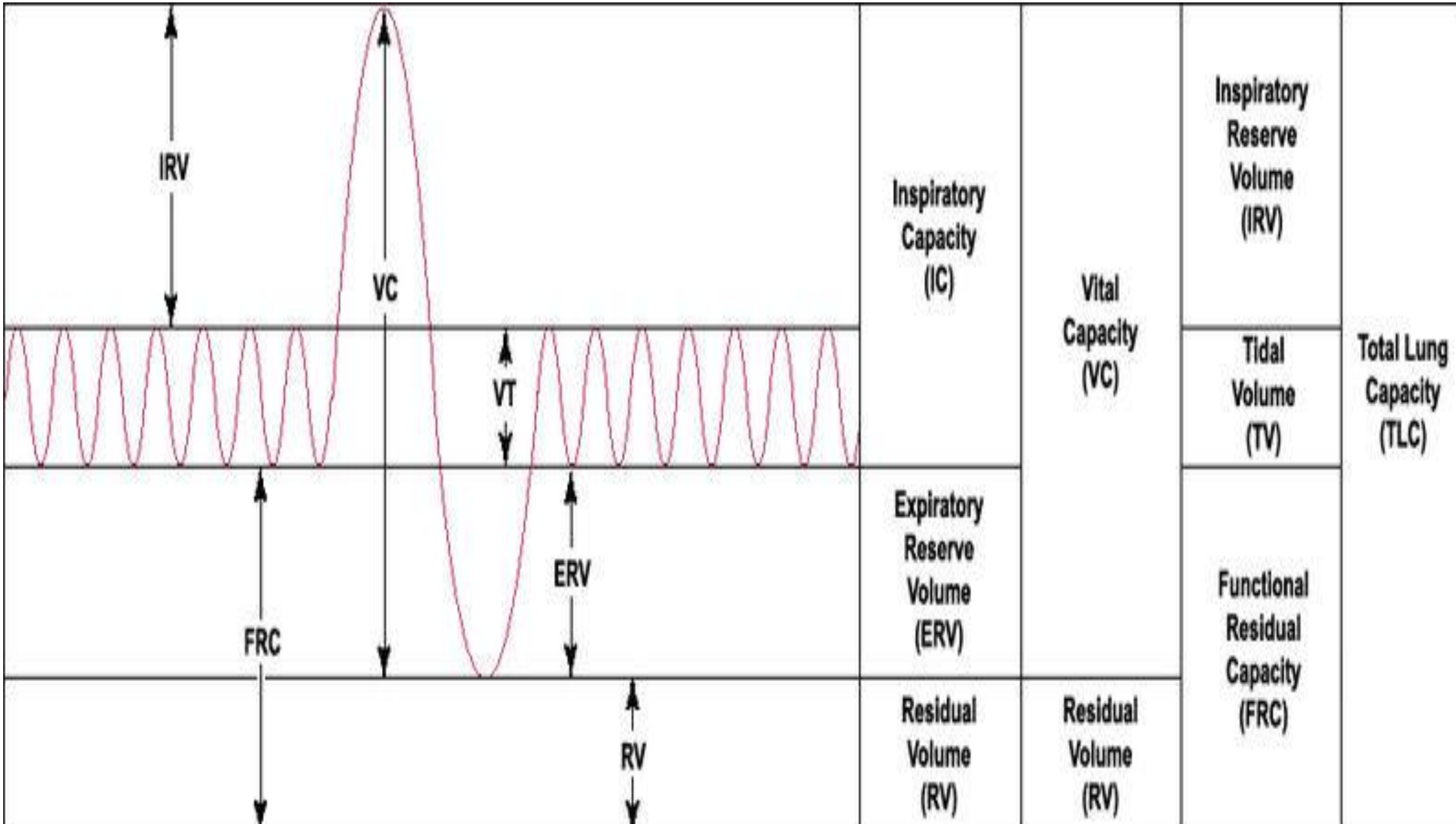
- The **carotid body** in the carotid arteries have receptors that respond to a drop in O_2.
- Their activation is important in situations (e.g., at high altitude) where oxygen supply is inadequate but there has been no increase in the production of CO_2.

Local Control of Breathing

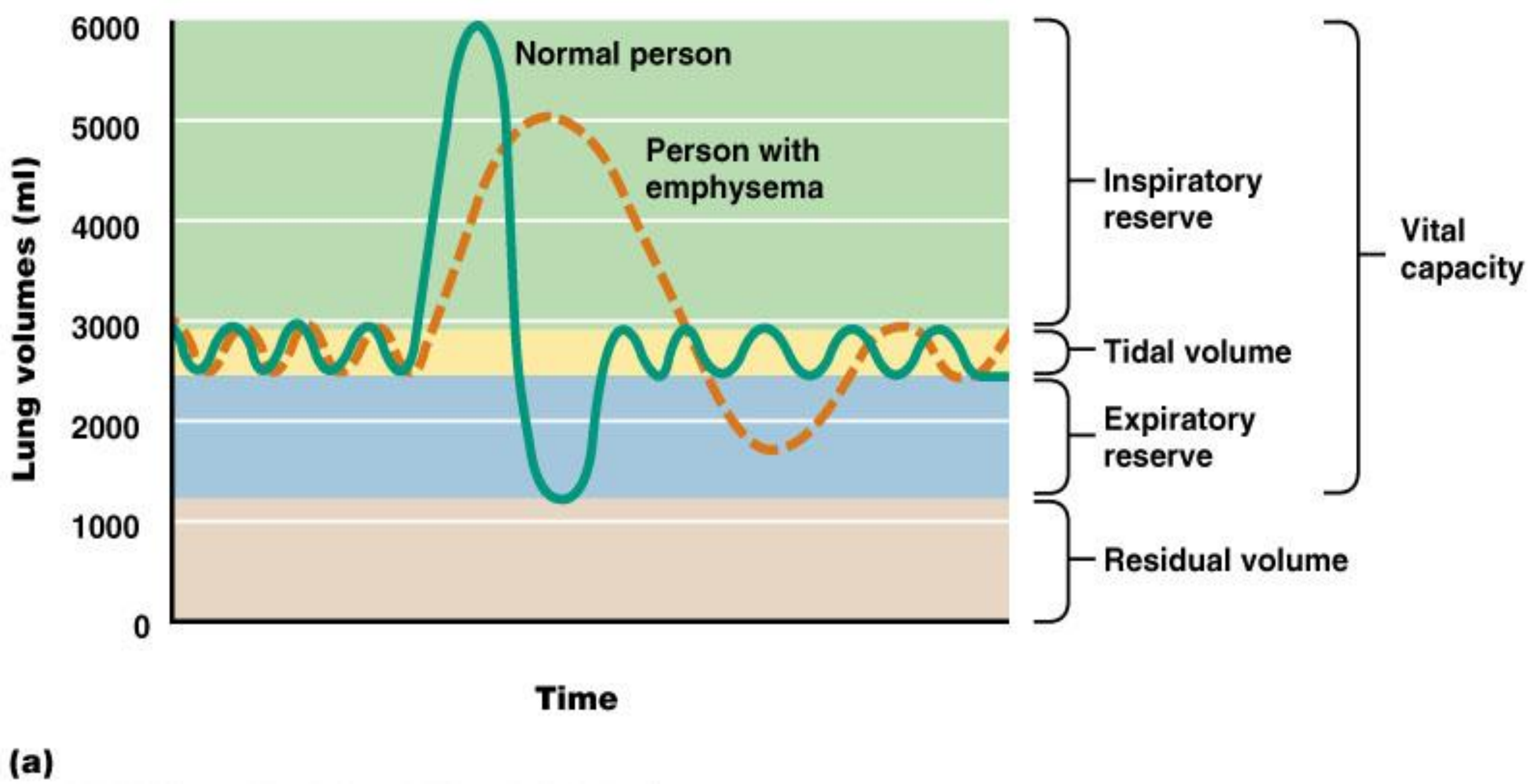
- The smooth muscle in the walls of the bronchioles is very sensitive to the concentration of **carbon dioxide**.
- A rising level of CO_2 causes the bronchioles to dilate. This lowers the resistance in the airways and thus increases the flow of air in and out.

The Lung volumes and capacities

- **Lung volumes** refer to physical differences in lung volume.
- **Lung capacities** represent different combinations of lung volumes, usually in relation to inhalation and exhalation.
- Most of the lung volumes and capacities are determined by the **Spirometer**


IRV
VC
VT
ERV
FRC
RV
Inspiratory Capacity (IC)
Expiratory Reserve Volume (ERV)
Residual Volume (RV)
Vital Capacity (VC)
Residual Volume (RV)
Inspiratory Reserve Volume (IRV)
Tidal Volume (TV)
Functional Residual Capacity (FRC)
Total Lung Capacity (TLC)

Measurement of Lung Capacity



Lung volumes:

- 1) **Tidal volume**: (T.V) 500 c.c.
  - It is the volume of air inspired or expired during rest.
- 2) **Inspiratory Reserve volume**: (I.R.V) 3000cc.
  - It is the maximum volume of air which can be inspired after normal inspiration.
- 3) **Expiratory reserve volume**: (E.R.V) 1000 c.c.
  - It is the maximum volume of air which can be expired after normal expiration.
- 4) **Residual volume**: (R.V) 1200 c.c.
  - It is the volume of air remaining in the lungs after maximal expiration. It can't be expelled to atmosphere except after opening of the chest wall and squeezing the lungs.

Lung capacities

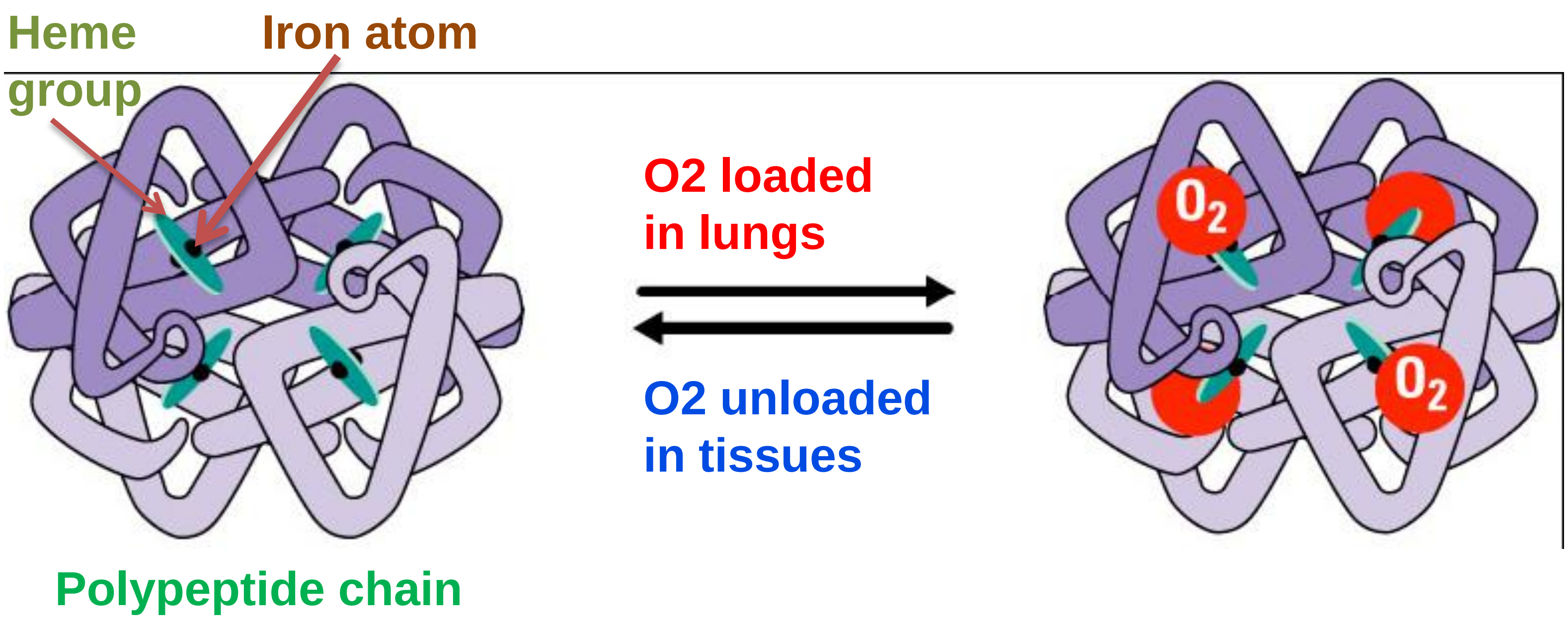
- 1**. Inspiratory capacity**: 3500 c.c.
  - It is the maximum volume of air which can be inspired after normal expiration. It equals T.V (500) + I.R.V (3000) = 3500 c.c.
- 2**. Functional Residual capacity**: 2200 c.c.
  - It is the volume of air remaining in the lung after normal expiration. It equals E.R.V (1000) + R.V (1200) = 2200 c.c.
- 3. **Vital capacity**: (V.C) 4500 c.c.
  - It is the volume of air given out by maximal expiration after maximal inspiration. It equals I.R.V (3000) + T.V (500) + E.R.V (1000) = 4500 c.c. VC = IRV+TV+ERV=TLC-RV
- 4. **Total lung capacity**: (T.L.C) 5700 c.c.
  - It is the volume of air contained in the lungs after deepest inspiration. It equals all lung volumes = 5700 c.c.
  - Total lung capacity = vital capacity (VC) + residual volume (RV)

- Tidal volume
  - The amount of air that moves in or out in one normal breath (~500 ml.)
- Inspiratory reserve volume
  - The amount of air that can be inhaled beyond the normal indrawn breath (~2900 ml.).
- Expiratory reserve volume
  - The amount of air that can be exhaled beyond the normal exhaled breath (~1100 ml.).
- Vital capacity
  - The amount of air that can be inhaled in the deepest breath and exhaled completely (~4500 ml.).
    Vital capacity = tidal volume + inspiratory reserve volume + exploratory reserve volume.
- Residual volume
  - The amount of air that cannot be expelled from the lungs no matter how hard one tries (~1200 ml.).
- Total lung capacity
  - The amount of air that can be accommodated by the lungs. Total lung capacity = vital capacity + residual volume

OxyHemoglobin Dissociation Curve

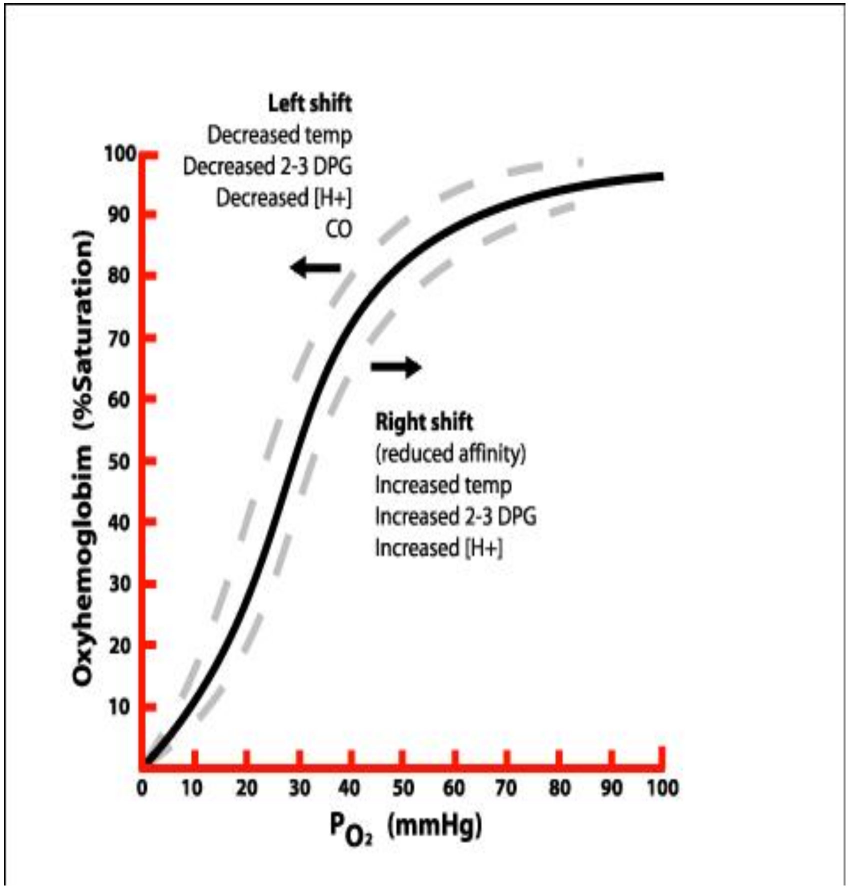
OxyHemoglobin Dissociation Curve

Hemoglobin loads up when O2 concentration is high and unloads when it is low.
Four oxygens per hemoglobin max.



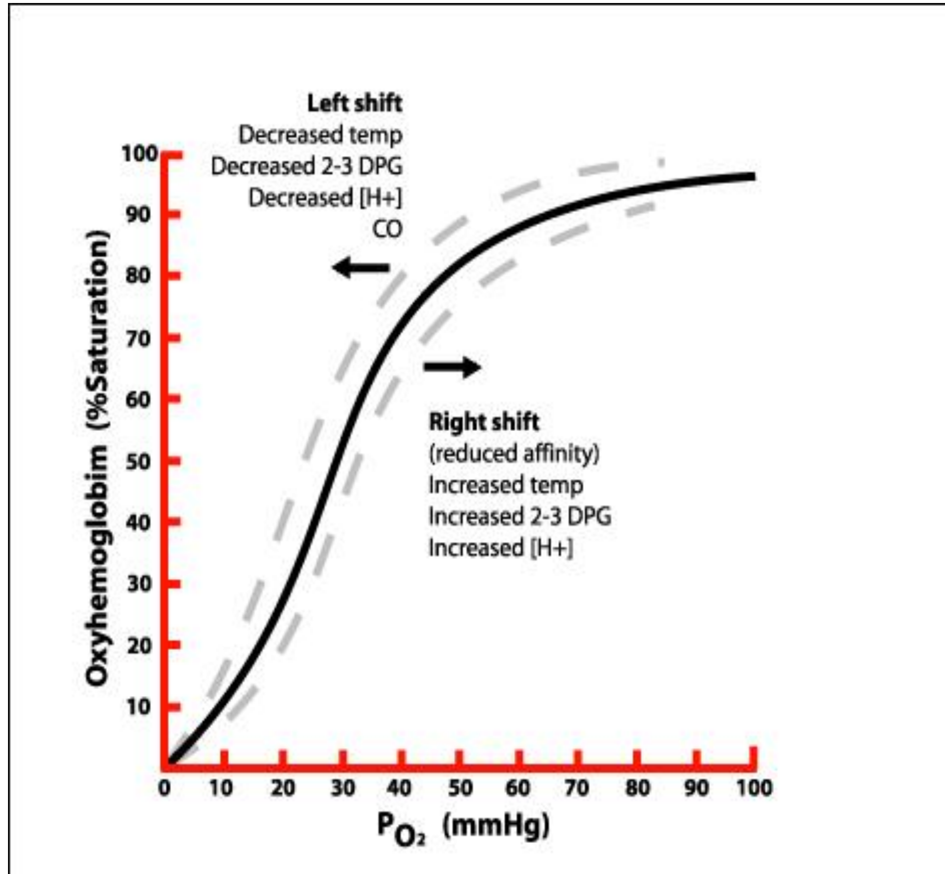
OxyHemoglobin Dissociation Curve

- **Describes** the relationship between available oxygen and amount of oxygen carried by hemoglobin.
- **Shows** the percent saturation of haemoglobin at various partial pressures of oxygen.



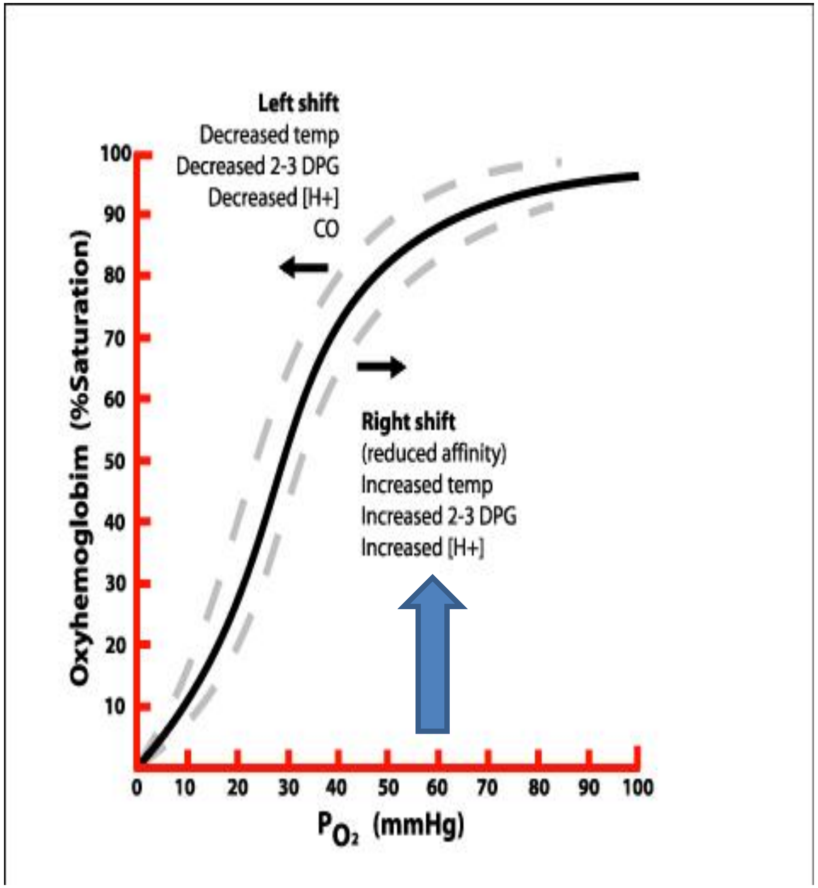
OxyHemoglobin Dissociation Curve

- The horizontal axis is **P O_2**, or the amount of oxygen available.
- The vertical axis is **SO_2**, or the amount of hemoglobin saturated with oxygen.



OxyHemoglobin Dissociation Curve

- Once the **PO_2** reaches **60 mm Hg the curve is almost flat**, indicating there is little change in saturation above this point.
  - So, **PO_2** of 60 or more is usually considered adequate.
  - But, at less than 60 mm Hg the curve is very steep, and small changes in the **PO_2** greatly reduce the **SO_2**.



OxyHemoglobin Dissociation Curve

- The term "**affinity**" is used to describe oxygen's attraction to hemoglobin binding sites.
  - Affinity changes with:
    - variation in pH,
    - temperature,
    - **C O_2** (PC O_2) and,
    - **2,3,-DPG** (a metabolic by-product which competes with O2 for binding sites).

OxyHemoglobin Dissociation Curve

- **Normally**, the curve starts with:
  - pH at 7.4,
  - temperature at 37 C,
  - **PCO2** at 40 mm Hg.
- Changes from these values are called "**shifts**".

OxyHemoglobin Dissociation Curve

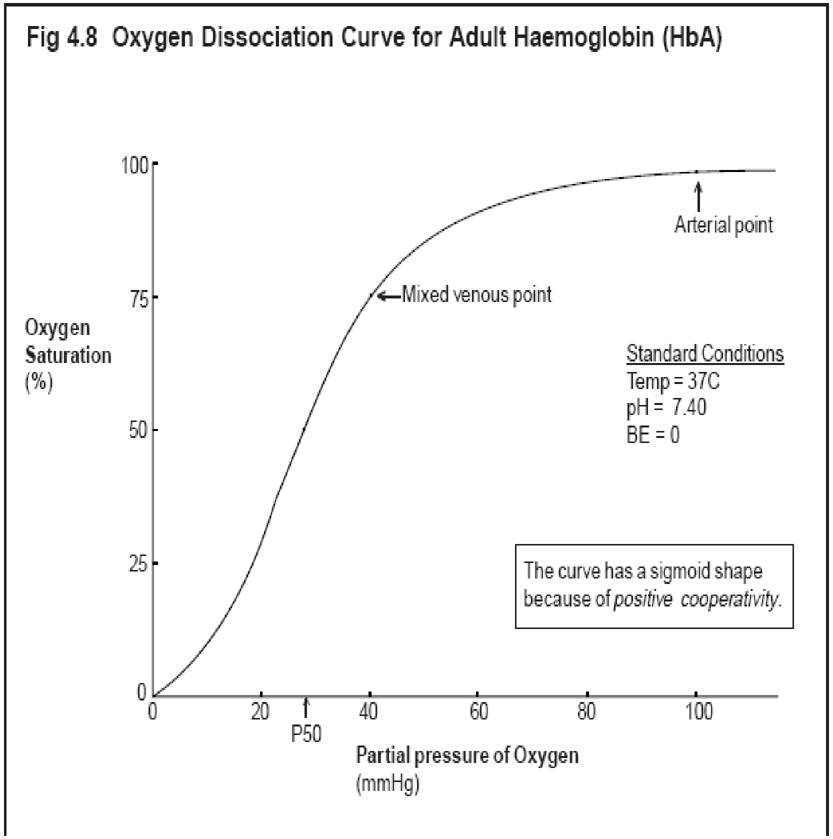
- **A left shift will increase oxygen's affinity for hemoglobin.**
  - oxygen will have a higher affinity for hemoglobin.
  - **S O_2** will increase at a given P O_2, but more of it will stay on the hemoglobin and travel back through the lungs without being used. This can result in tissue **hypoxia** even when there is sufficient oxygen in the blood.
  - Left shift condition (eg. alkalosis, hypothermia)

OxyHemoglobin Dissociation Curve

- **A right shift decreases oxygen's affinity for hemoglobin.**
  - oxygen has a lower affinity for hemoglobin. Blood will release oxygen more readily.
  - This means more O_2 will be released to the cells, but it also means less oxygen will be carried from the lungs in the first place.
  - In a right shift (acidosis, fever)

OxyHemoglobin Dissociation Curve

- shows the % saturation of Hb at various partial pressures of oxygen.
- Expressed as P50 value.
  - the pressure at which the red blood cells are 50% saturated with oxygen



OxyHemoglobin Dissociation Curve

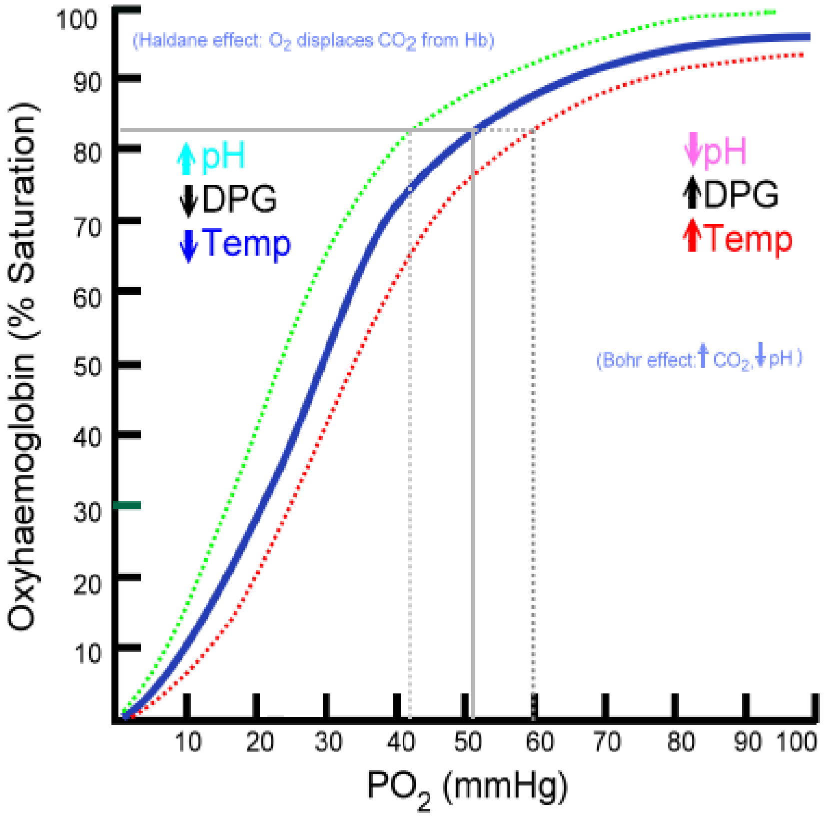
- shows the equilibrium of oxyhaemoglobin and nonbonded haemoglobin at various partial pressures.
- **At Lungs (high P O2),** Hb binds to O_2 to form oxyhaemoglobin.
  - When the blood is fully saturated all the red blood cells are in the form of oxyhaemoglobin.
- **At Tissues (P O2 will decrease).**
  - the oxyhaemoglobin releases the oxygen to form haemoglobin.

OxyHemoglobin Dissociation Curve

- Carbon monoxide (CO) interferes with the O_2 transport function of blood by combining with Hb to form **carboxyhaemoglobin (COHb).**
- CO has about 240 times the affinity of O_2 for Hb.
- small amounts of CO can tie up a large proportion of the Hb in the blood, thus making it unavailable for O_2 carriage.
- COHb also shifts the O_2 dissociation curve to the left, thus interfering with the unloading of O_2 (toxicity of CO).

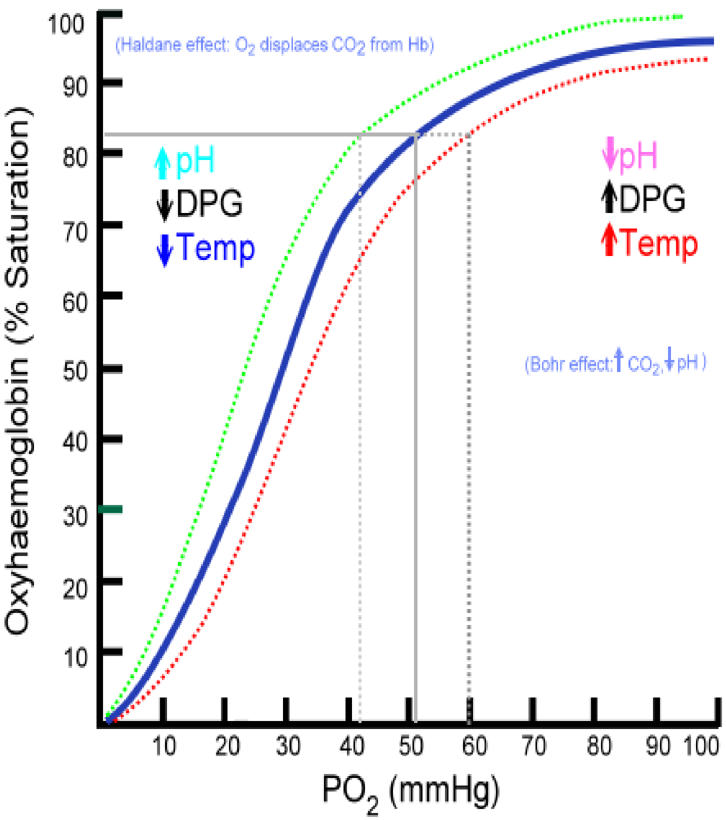
Factors that Influence Oxygen Binding

- **Temperature**
  - Increasing the temperature denatures the bond between O_2 and Hb, which increases the amount of O_2 and Hb and decreases the concentration of oxyhemoglobin.
  - The dissociation curve shifts to the right.



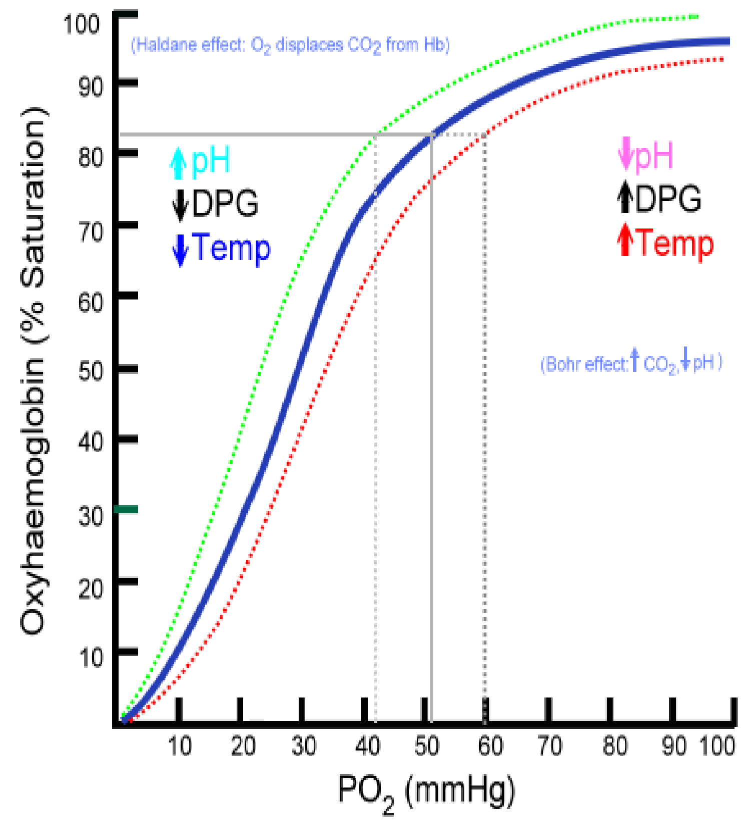
Factors that Influence Oxygen Binding

- **pH**
  - A decrease in pH by addition of CO_2 or other acids causes a **Bohr Shift.**
  - A Bohr shift is characterized by causing more oxygen to be given up as $P\ O_2$ increases.
  - The dissociation curve shifts to the right.



Factors that Influence Oxygen Binding

- **(DPG) 2,3-Diphosphoglycerate**
  - DPG binds to haemoglobin which rearranges the haemoglobin molecules, thus decreasing the affinity of oxygen for haemoglobin.
  - The curve shifts to the right.

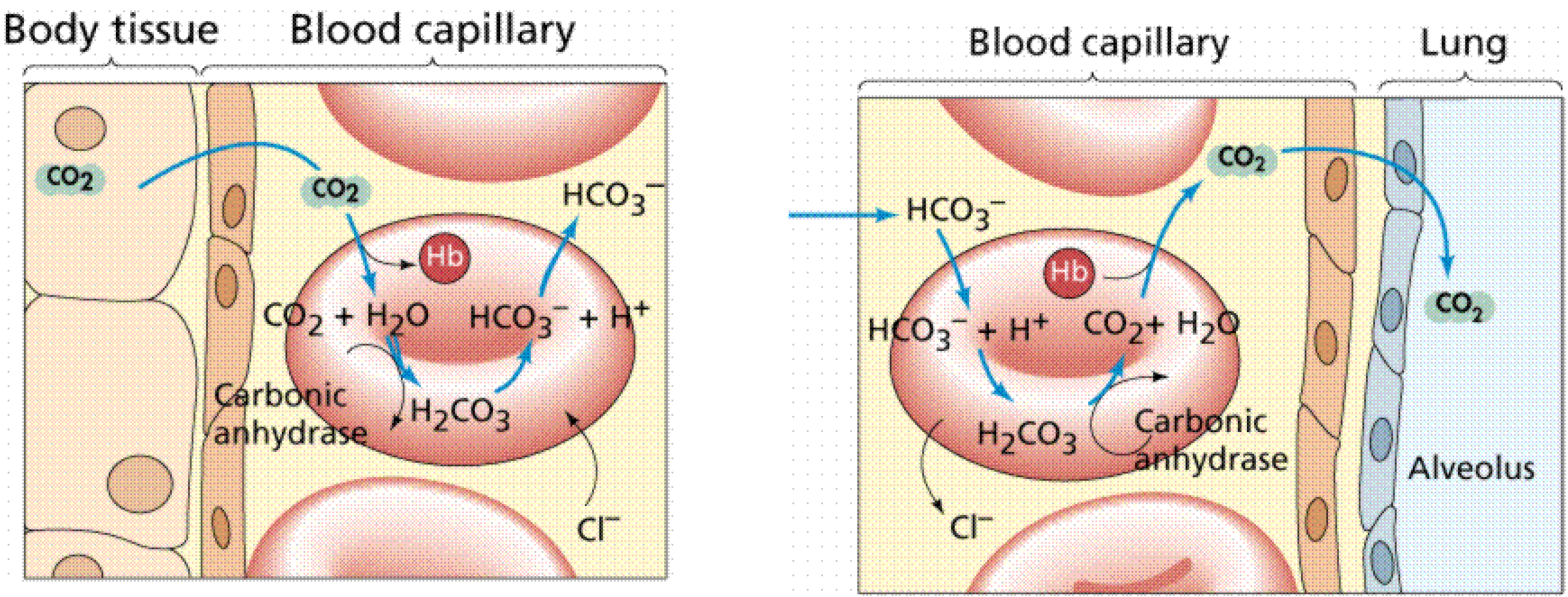


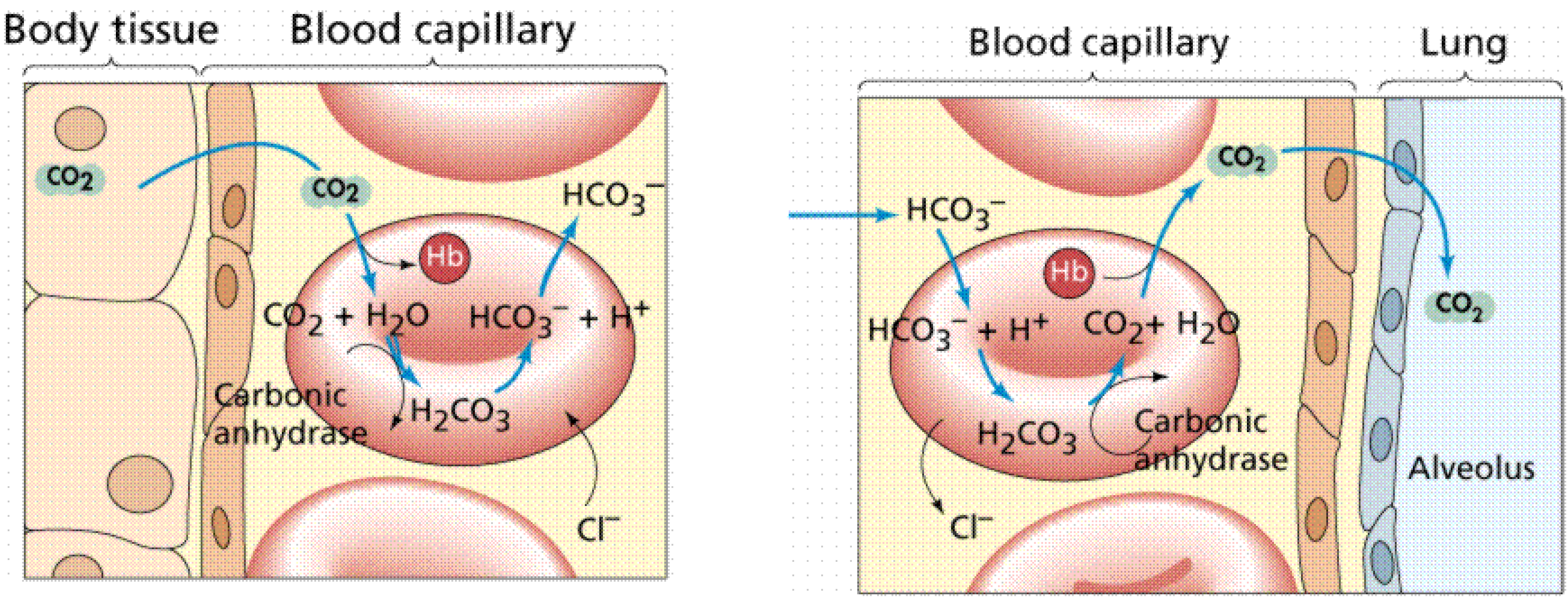
Bohr Effect

- CO_2 diffuses into alveoli when the blood passes through the lungs, this result in a
  - decrease in the blood pCO_2 and also
  - decreases H ion concentration (due to the decrease in blood carbonic acid).
  - This shifts the dissociation curve to the left.
- The amount of oxygen that binds with hemoglobin at any given alveolar PO_2 increases and provides for greater O_2 transport to the tissues.

Boher effect function:

- Boher effect facilitates oxygen transport as hemoglobin binds to oxygen in the lungs, then releases it in the tissues.


Body tissue
Blood capillary
CO_2
CO_2
Hb
HCO_3^-
$CO_2 + H_2O$
$HCO_3^- + H^+$
Carbonic anhydrase
H_2CO_3
Cl^-
Blood capillary
Lung
CO_2
HCO_3^-
Hb
$HCO_3^- + H^+$
$CO_2 + H_2O$
H_2CO_3
Carbonic anhydrase
CO_2
Alveolus
Cl^-



Body tissue
Blood capillary
CO_2
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Blood capillary
Lung
HCO_3^-
CO_2
Hb
$HCO_3^- + H^+$
$CO_2 + H_2O$
H_2CO_3
Carbonic anhydrase
CO_2
Alveolus
Cl^-

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- Residual volume
  - The amount of air that cannot be expelled from the lungs no matter how hard one tries (~1200 ml.).
- Total lung capacity
  - The amount of air that can be accommodated by the lungs. Total lung capacity = vital capacity + residual volume

RESPIRATORY SYSTEM

Respiratory system

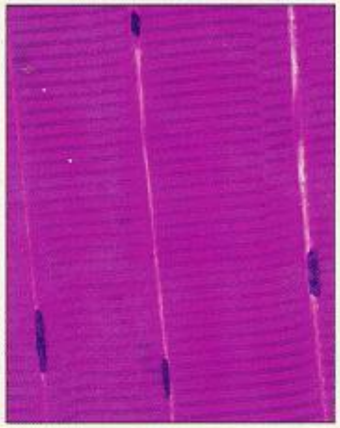
Oxygen Delivery System

Effectors

Muscle structure and function

Effectors

- Effectors are muscles and glands.
- Excitable cells
  - neurons
  - muscle cells
  - gland cells
  - receptor cells



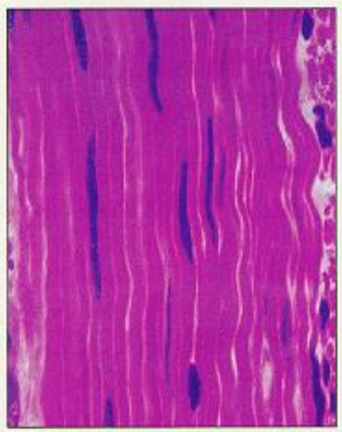
a

TYPE: Skeletal muscle

DESCRIPTION: Long, striated cells with multiple nuclei

COMMON LOCATIONS: In skeletal muscles

FUNCTION: Contraction for voluntary movements



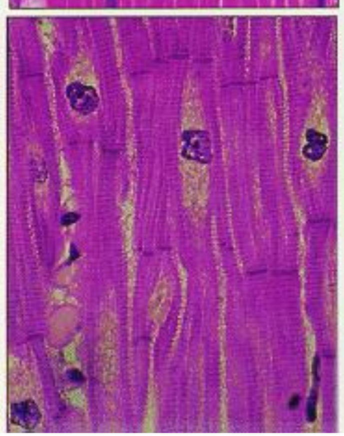
b

TYPE: Smooth muscle

DESCRIPTION: Long, spindle-shaped cells, each with a single nucleus

COMMON LOCATIONS: In hollow organs (e.g., stomach)

FUNCTION: Propulsion of substances along internal passageways



c

TYPE: Cardiac muscle

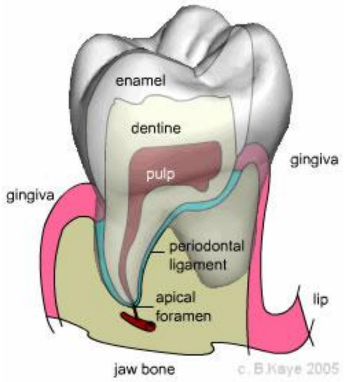
DESCRIPTION: Branching, striated cells fused at plasma membranes

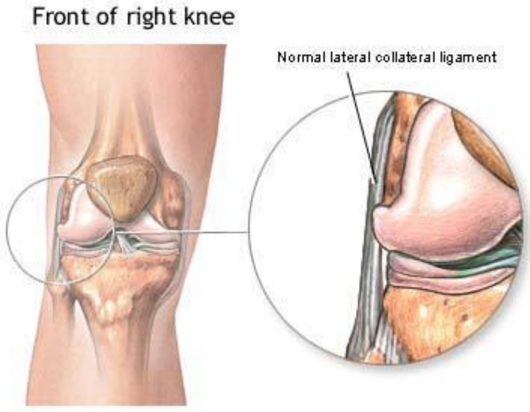
COMMON LOCATIONS: Wall of heart

FUNCTION: Pumping of blood in the circulatory system

Human muscular system

- 600 skeletal muscles
- Skeletal muscles transmit contractile force to bones for movement.
- **Tendons:** strap of dense connective tissue, attaches some **muscle to bone**.
- **Ligament**: bone to bone



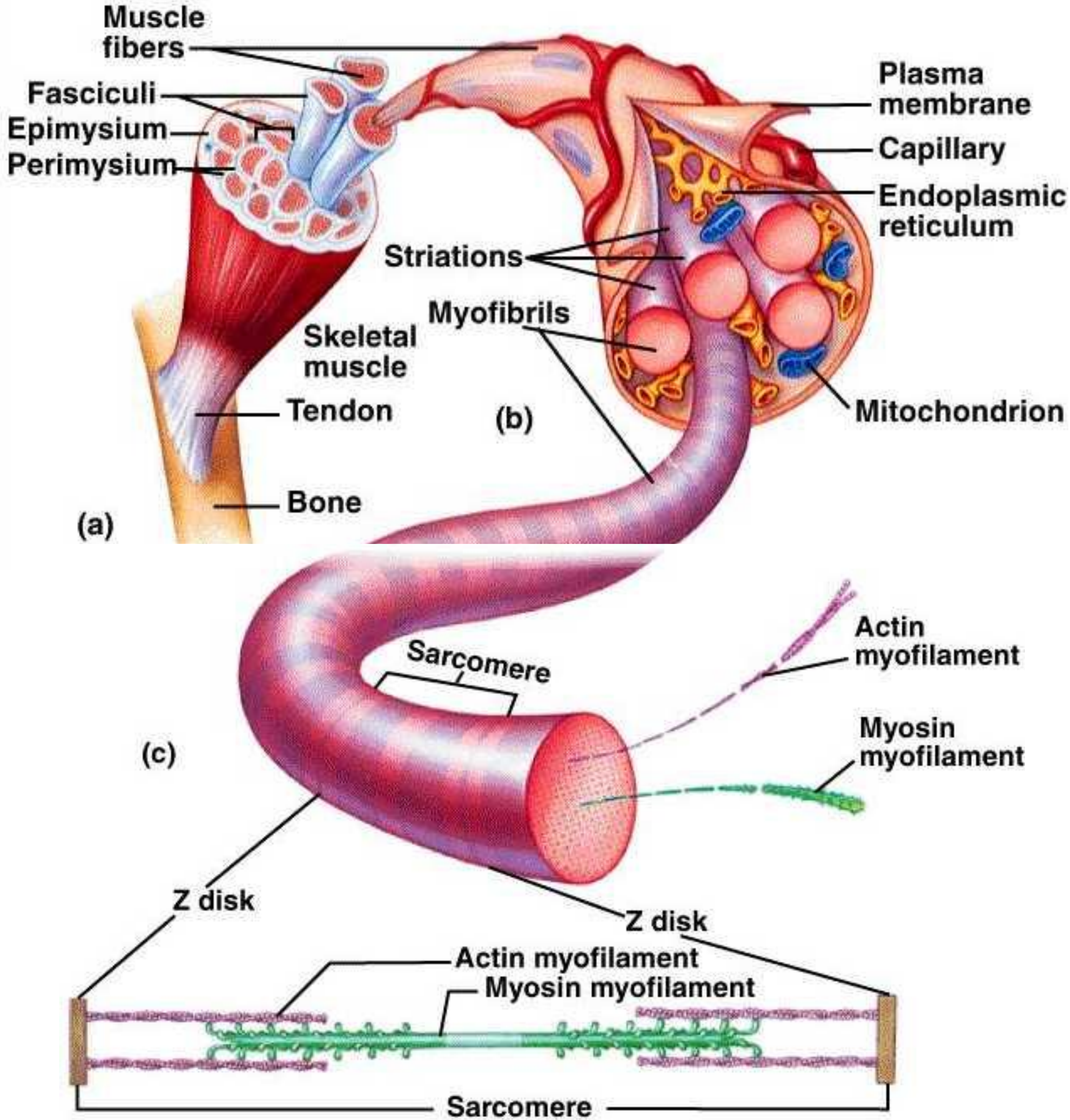


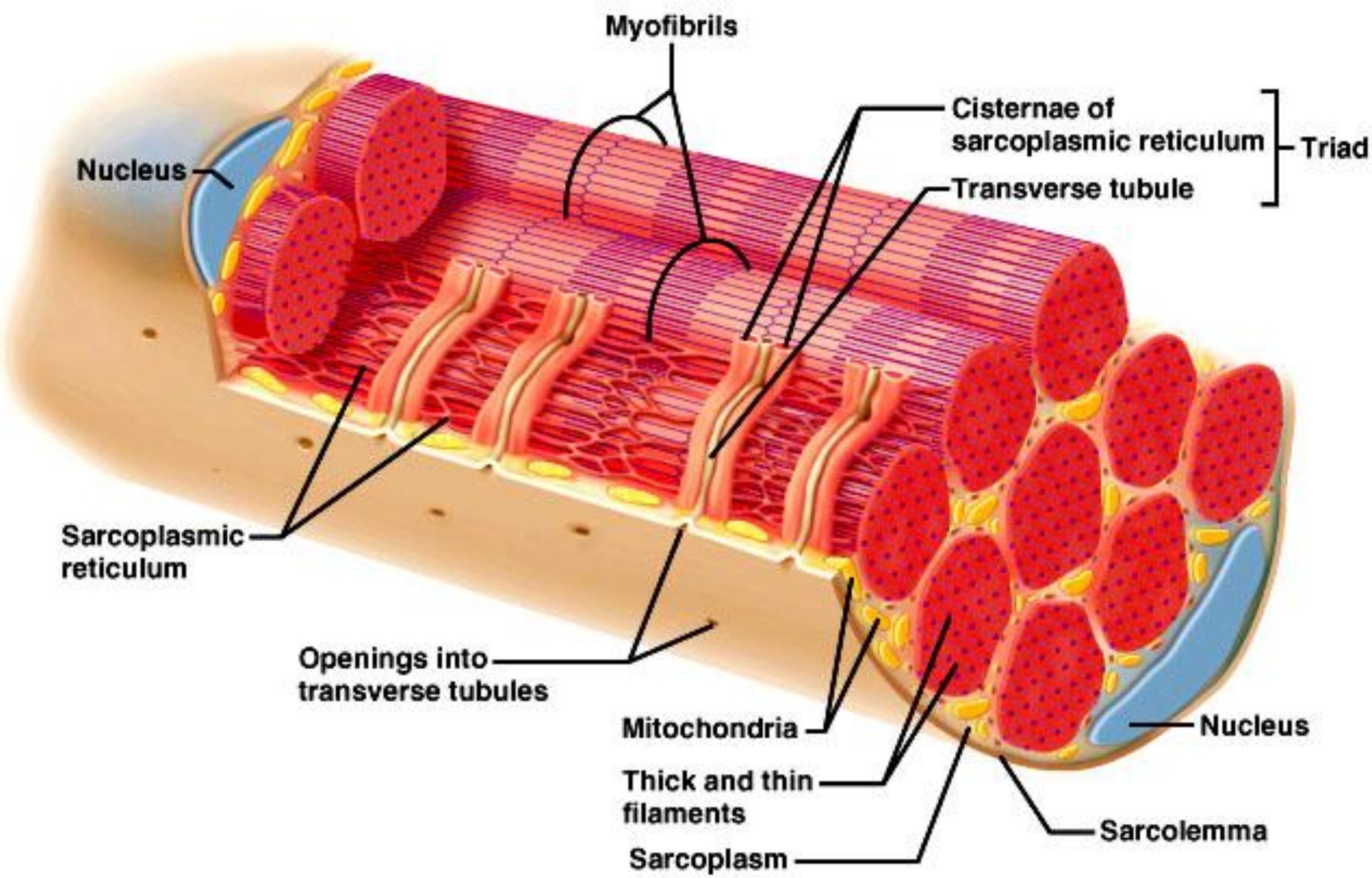
Characteristics of muscle:

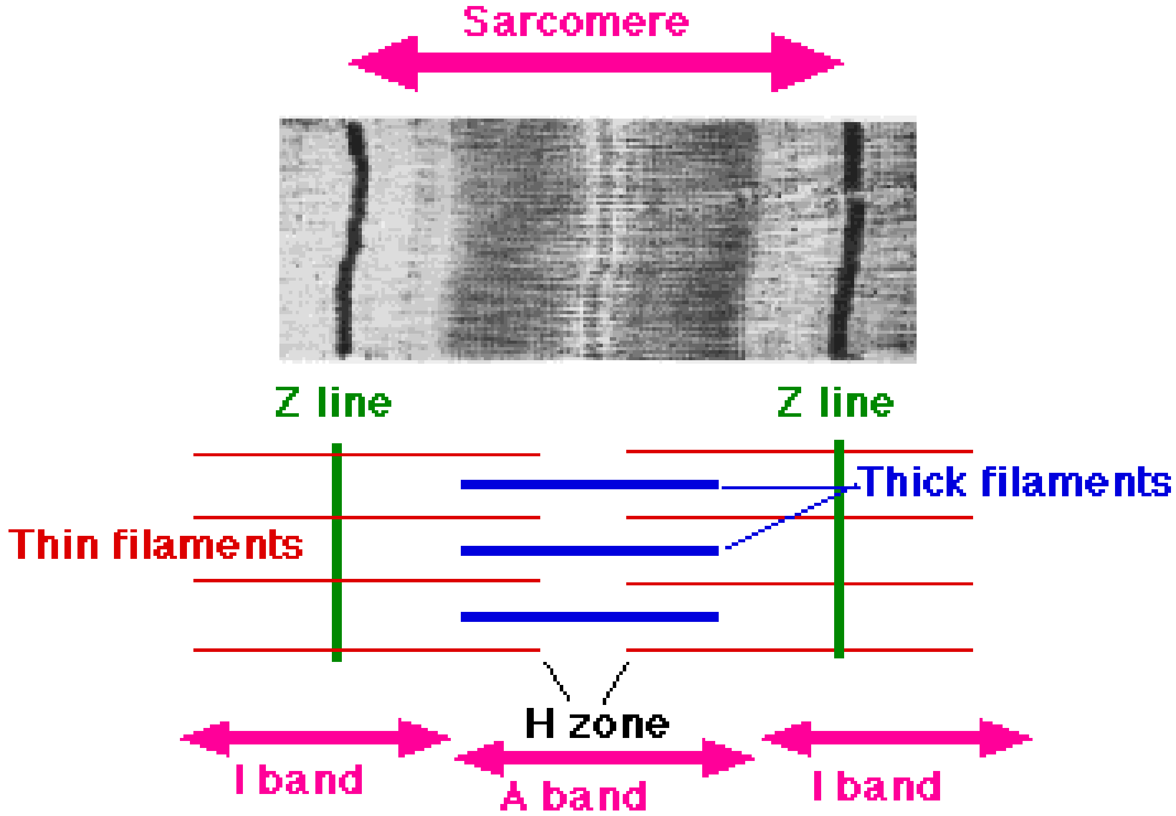
- **excitability** = responds to stimuli
- **contractility** = able to shorten in length
- **extensibility** = stretches when pulled
- **elasticity** = tends to return to original shape & length after contraction or extension

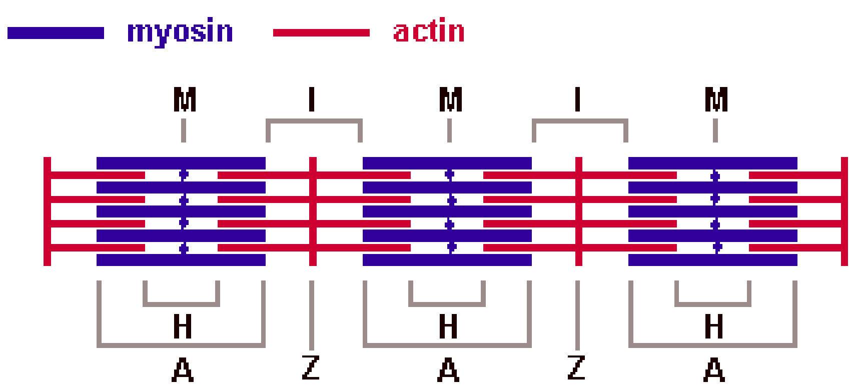
Functions of muscle:

- motion
- maintenance of posture
- heat production


Muscle fibers
Fasciculi
Epimysium
Perimysium
Skeletal muscle
Tendon
Bone
(a)
Plasma membrane
Capillary
Endoplasmic reticulum
Striations
Myofibrils
Mitochondrion
(b)
Sarcomere
Actin myofilament
Myosin myofilament
(c)
Z disk
Z disk
Actin myofilament
Myosin myofilament
Sarcomere


Myofibrils
Cisternae of sarcoplasmic reticulum
Triad
Transverse tubule
Nucleus
Sarcoplasmic reticulum
Openings into transverse tubules
Mitochondria
Thick and thin filaments
Sarcoplasm
Nucleus
Sarcolemma



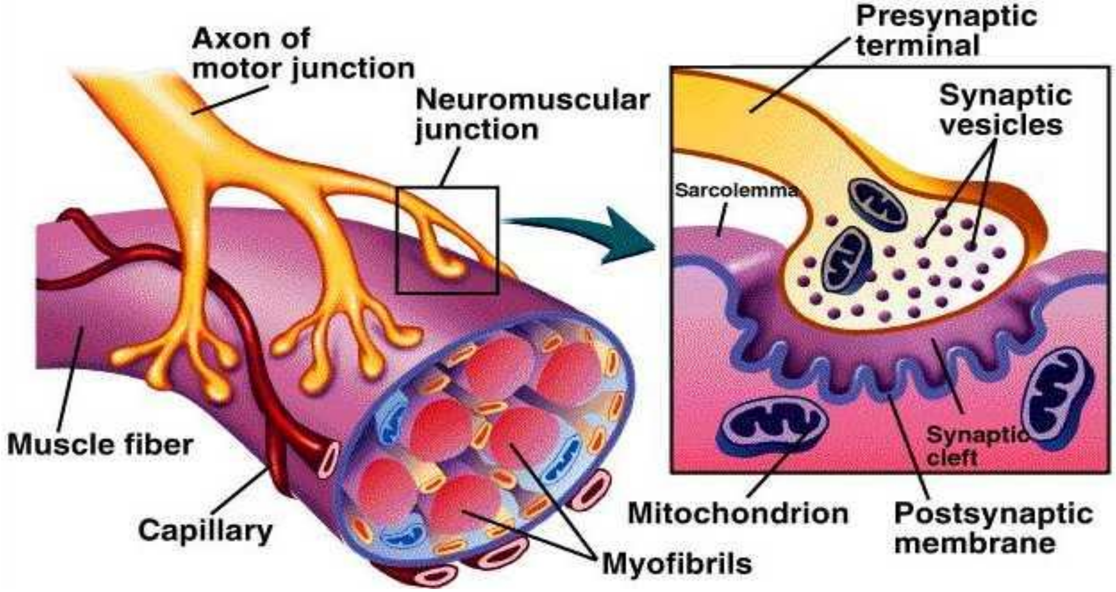


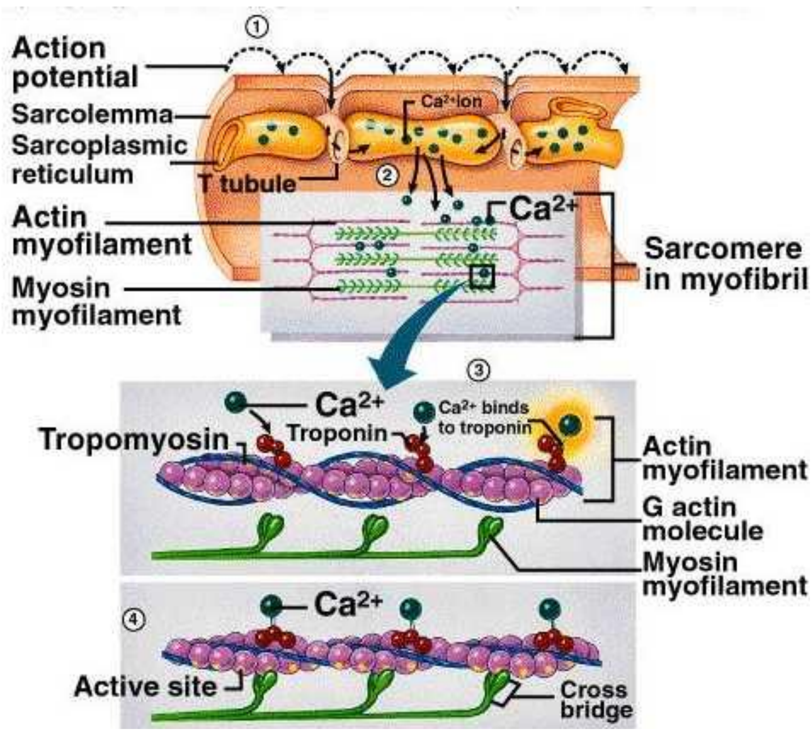
Bands and lines in the contractile apparatus of skeletal muscle

Skeletal muscle structure and function

- A muscle has bundles of muscle cells
- A muscle cell has many myofibrils.
- Myofibril has many sarcomers.
- Sarcomer has many myofilaments [thick & thin[
- Sarcomer is the basic unit of contraction

Neuromuscular Junction





Neuromuscular junction

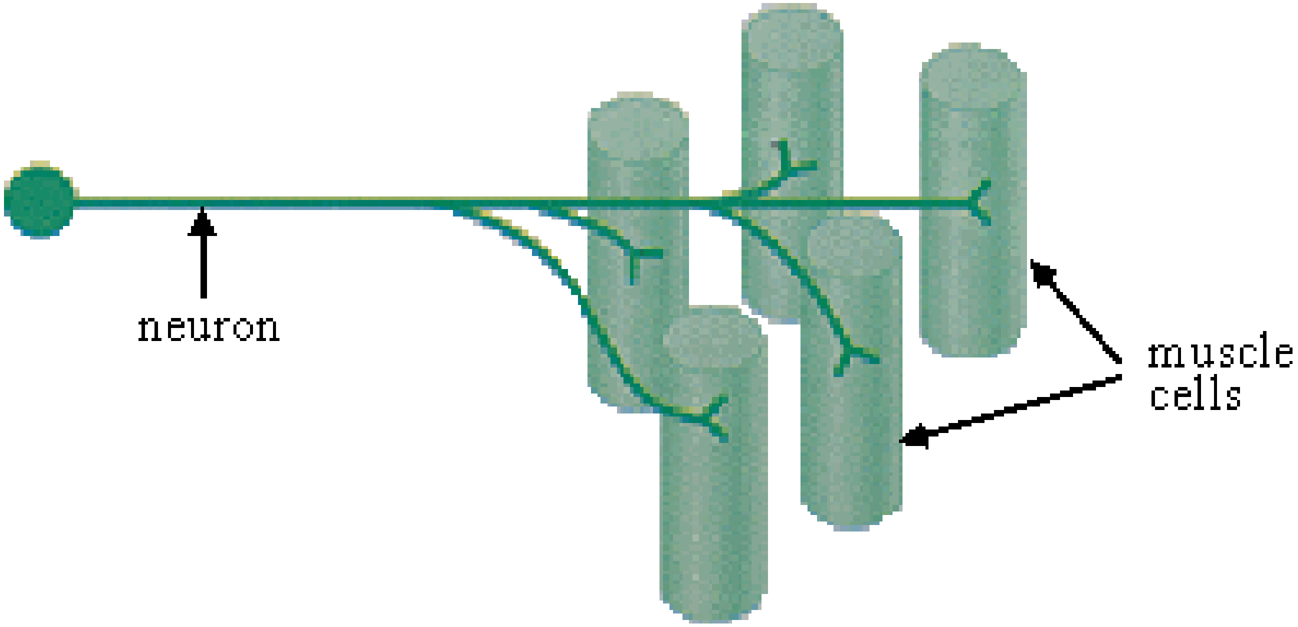
- The branch of a motor nerve fiber terminates on muscle fiber.
- Nerve impulse travel down a motor fiber cause synaptic vesicles to release **Neurotransmitter** acetylecholine (Ach) which diffuse across synaptic cleft.
- When ACh is received by the sarcolemma of a muscle fiber, impulses begin and lead to muscle fiber contraction, and finally, muscle contraction.

Changes occurring during muscle contraction

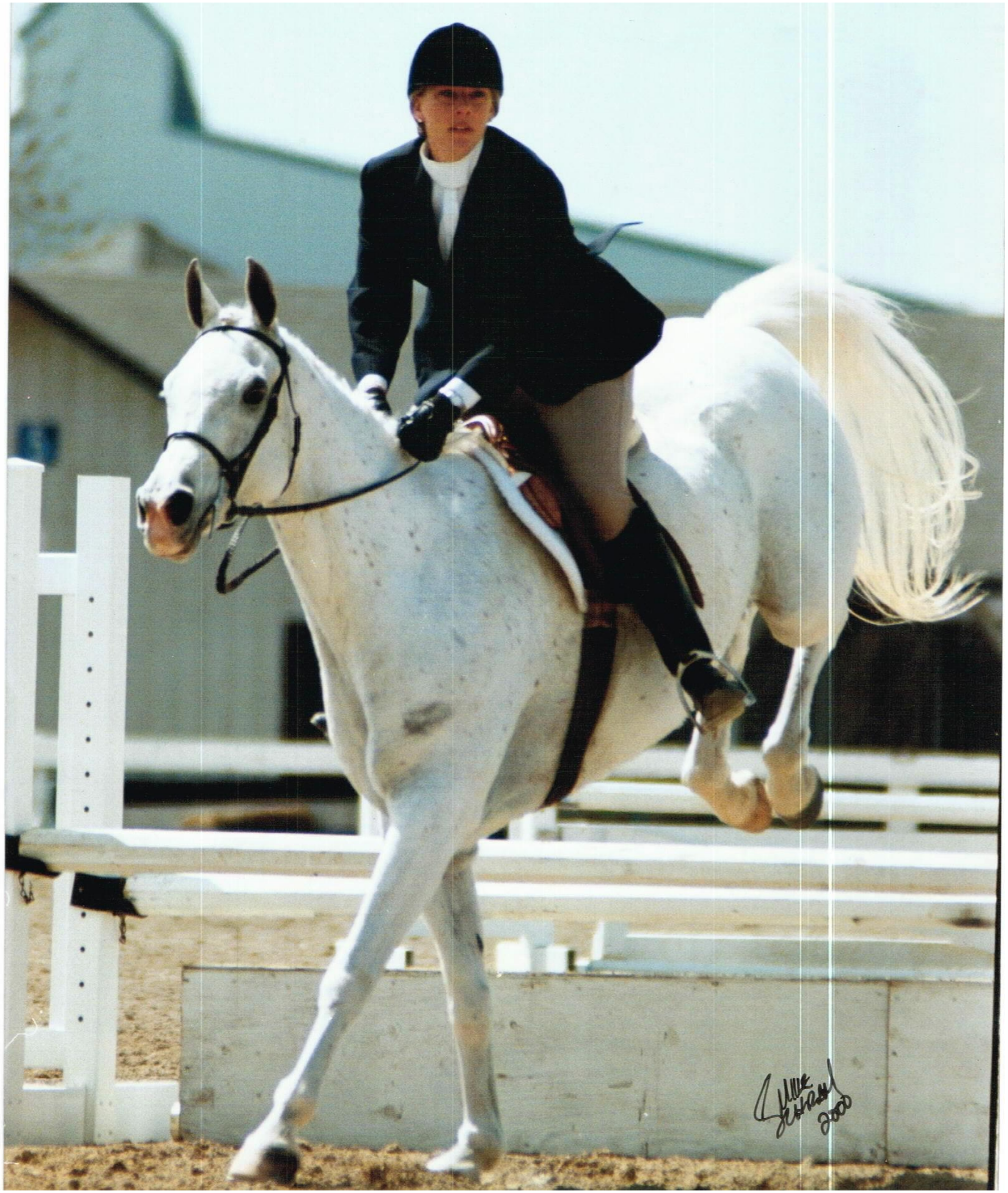
- **1- Electrical changes**
  - Nerve impulse (electrical stimulus) cause release of neurotransmitters that leads to depolarization of sarcolemma.
- **2- Chemical changes**
  - Breakdown of glycogen to glucose to produce ATP
- **3- Mechanical changes**
  - Sliding filament mechanism whereby the sarcomeres shorten (the Z-lines come closer together) by the action of the actin filaments sliding over the myosin filaments

MOTOR UNITS

The combination of the motor nerve cell (neuron) and all the muscle cells it innervates is known as a motor unit



When an electrical impulse travels down the axon, all muscle cells attached to the motor unit contract simultaneously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