

PHYSIOLOGY OF Cardiopulmonary System



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Study Objectives

By the end of the lecture, the student will be able

- 1. Identify the types and functions of blood vessels.**
- 2. Explain the divisions of circulation: Systemic vs. pulmonary circulation.**
- 3. Define cardiac autorhythmicity.**
- 4. Define key respiratory terms: Dead space, tidal volume, compliance, surfactant, hypoxia, dyspnea, orthopnea, apnea & cyanosis**
- 5. Describe the mechanism of breathing.**

Introduction

Anatomy of the Heart

4 Cardiac Chambers

2 atria (right and left) & 2 ventricles (right and left)

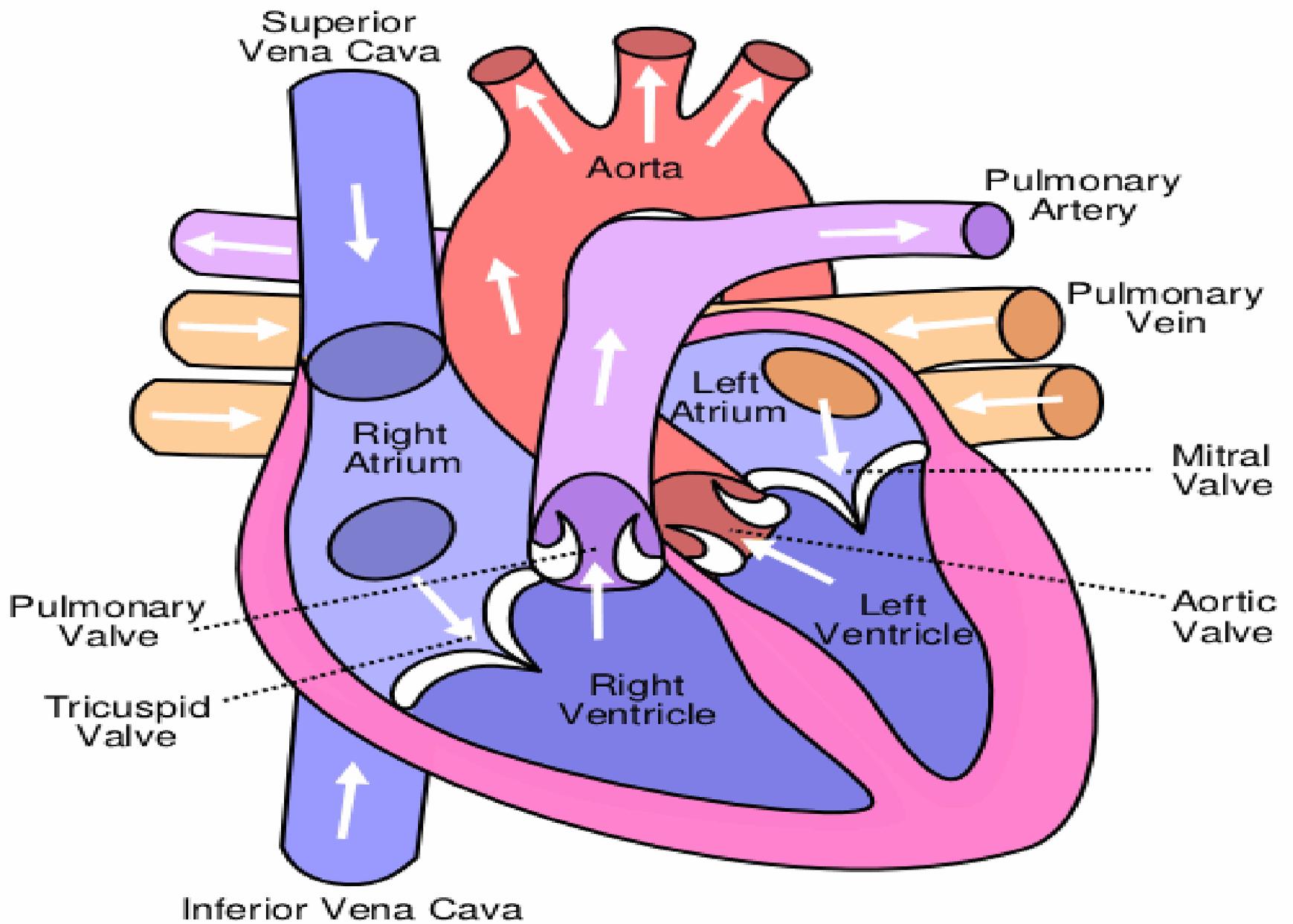
4 Cardiac Valves:

I-Atrioventricular (AV) Valves (mitral & tricuspus)

II-Semilunar Valves (aortic & pulmonary)

All valves have 3 cusps except mitral

Try Pulling My Aorta



Introduction

Anatomy of the Heart

- The heart wall is made up of three layers:

- **Epicardium:** Outside layer
 - This layer is the parietal pericardium.
 - The pericardial sac supports the heart and contains some fluid for lubrication.
- **Myocardium:** Middle layer.
 - Mostly cardiac muscle.
- **Endocardium:** Inner layer



Introduction

Anatomy of the Blood Vessels

There are 3 types of blood vessels:

a) Arteries & arterioles: They distribute the oxygenated blood from the heart to the tissues of the body.

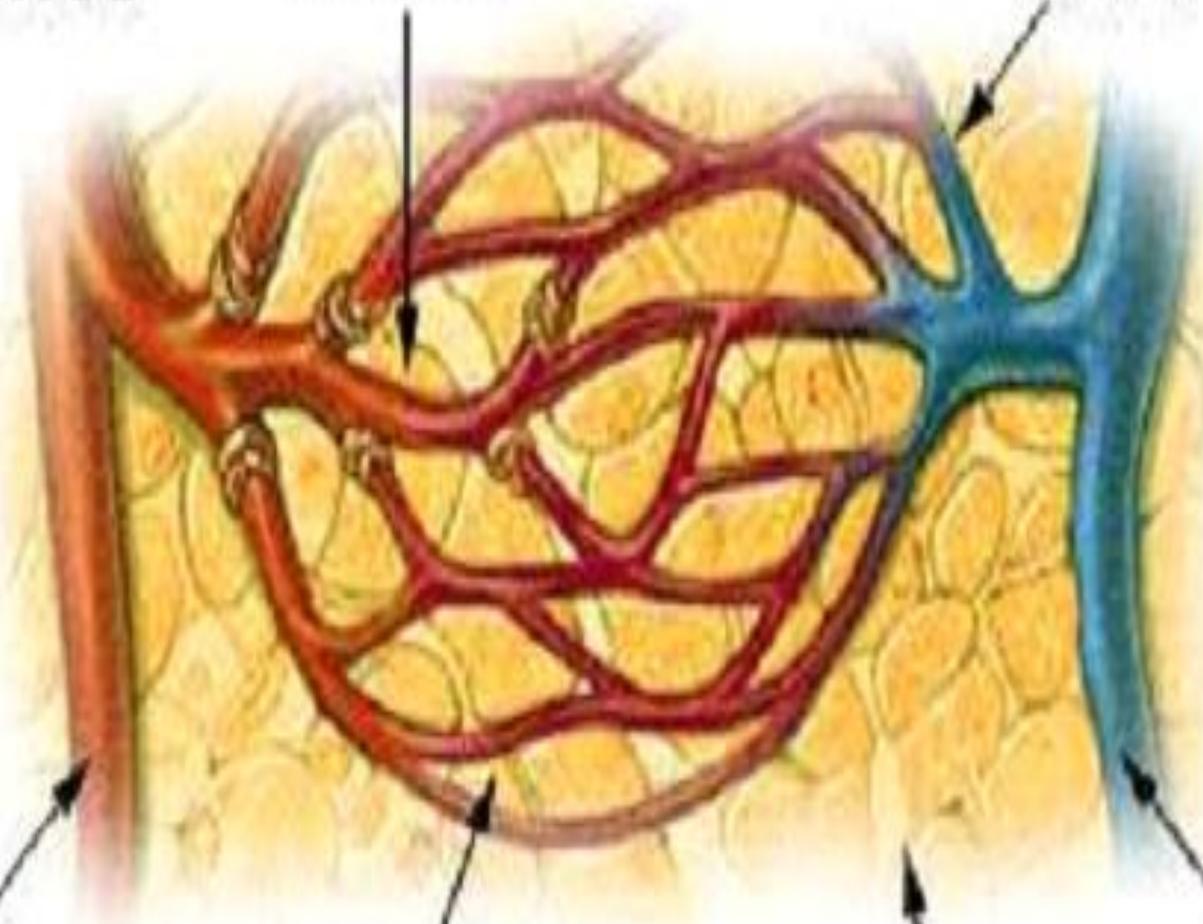
b) Capillaries: They allow the diffusion of gases, substances & fluids between the tissue cells & the blood. So, they act as interchanges system.

c) Veins & venules: They carry the none oxygenated blood from the tissues to the heart.

Capillaries

Arteriole

Venule



Artery

capillaries

Tissue cells

Vein

• Functions of Atria:

(It is **NOT** essential to life)

why

1-Blood reservoirs

2-Pumping 30% of venous return into the ventricles during their diastole (= relaxation).

3-Atria containing sinoatrial node which is important for beginning & spread of heart beat.

4-Atria specially the right, contain receptors of many cardiac reflexes.

GRAVITY لا تقل ان الدم ينزل بال

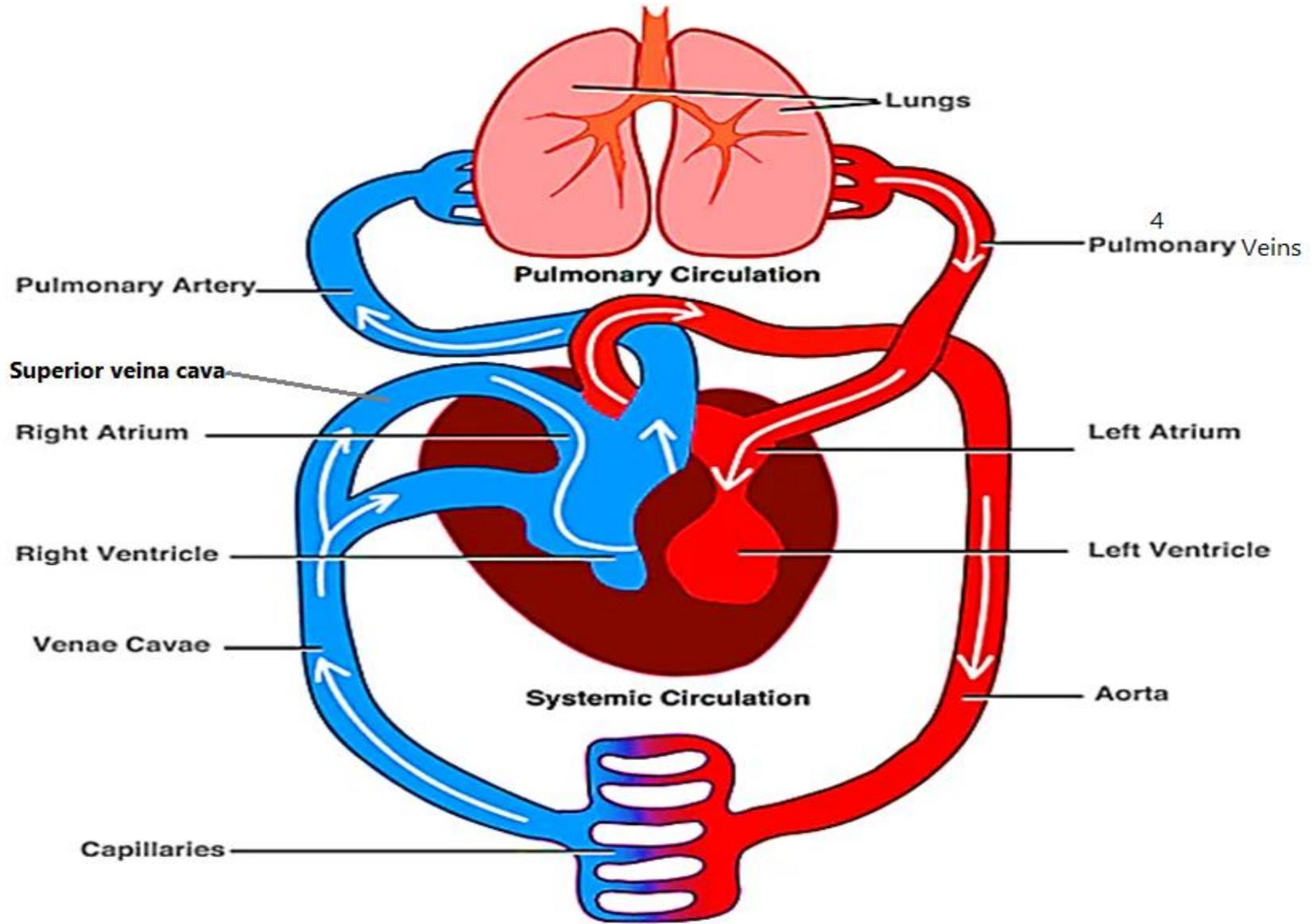
• Functions of Ventricles:

(It is essential to life) why

- They are the main cardiac pumps. The right ventricle (= pulmonary pump) pushes the blood to lungs & left ventricle (= systemic pump) pushes it into all body tissues. Stoppage of ventricular pumping is fatal within few minutes

Divisions of Circulations

Pulmonary and systemic circulation



Divisions of Circulations

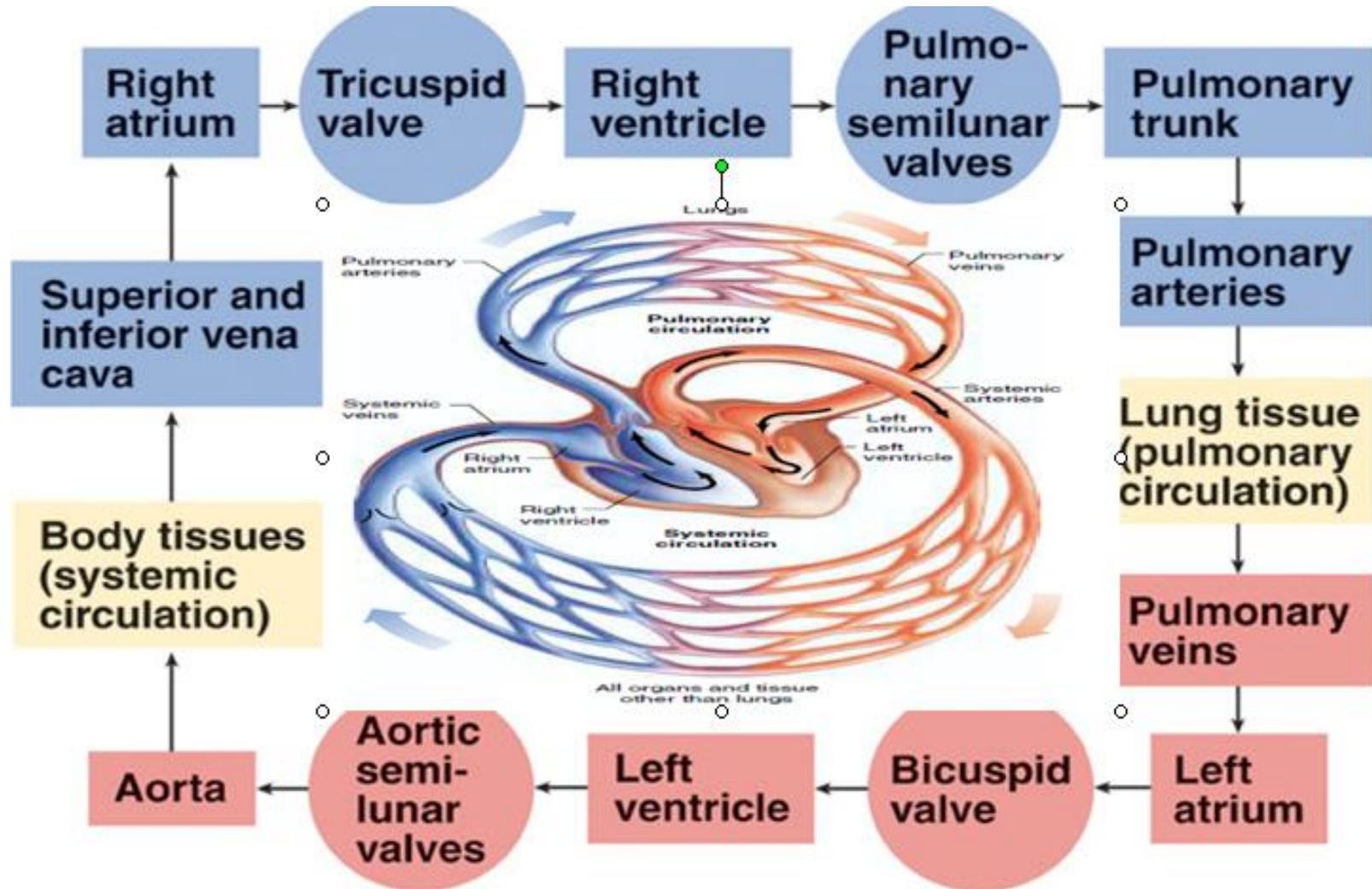
1- The Systemic (= General) Circulation:

- The left ventricle pumps its arterial blood into the aorta & its branches (arteries) ⇒ arterioles ⇒ capillaries (where the blood gives its O₂ to the tissues & takes CO₂ to become venous blood) ⇒ venules ⇒ veins ⇒ superior & inferior venae cavae ⇒ right atrium ⇒ right ventricle where the pulmonary circulation begins.

2- The Pulmonary (= Lesser) Circulation:

- The right ventricle pumps venous blood into pulmonary artery & its branches ⇒ pulmonary capillaries (where the blood is oxygenated & CO₂ removed to air & becomes arterial in nature) ⇒ pulmonary veins ⇒ left atrium & then to the left ventricles where the systemic circulation begins.

Divisions of Circulations



CARDIOVASCULAR SYSTEM

DEFINITIONS

1-Autorhythmicity: It is the ability of the cardiac muscle to beat spontaneously and regularly.-It is myogenic

2-Contractility: It is the ability of the cardiac muscle to contract.

3-Excitability: It is the ability of the cardiac muscle to respond to a stimulus.

-SA node is the pacemaker of the heart because the SA node has the highest rhythm (90 beats/min).

4-Conductivity: It is the ability of the cardiac muscle to transmit the excitation wave from one part of the heart to another.

CARDIOVASCULAR SYSTEM

DEFINITIONS

5-Vagal Tone is a continuous inhibitory effect by the vagi on the heart during rest \Rightarrow \downarrow the high SAN rhythm from about 90 \Rightarrow 70 impulses/min.

6-HEART RATE (HR) is the number of heart beats per minute = 60 – 100 beats/min [70 beats/min in average].

(1) **Tachycardia**: H.R. is more than 100 beats/min.

(2) **Bradycardia**: H.R. is less than 60 beats/min.

7-Cardiac Output (COP): It is the volume of blood pumped by each ventricle/ minute. It is about 5 litres /min. $COP = SV \times HR = 70 \times 70 = 4900 \text{ ml/min}$.

CARDIOVASCULAR SYSTEM

DEFINITIONS

8-Stroke Volume (SV) : It is the volume of blood pumped by each ventricle/beat. 70-90 ml / beat.

9-Arterial blood pressure (ABP):

It is the pressure of blood on the arterial wall.

The normal ABP for a resting adult male is between 100-140/ 60- 90 mm Hg [120/80 mm Hg in average].

10-Systolic Blood Pressure (SBP):

(normally it is 100- 140 mm Hg with average 120 mmHg).

11-Diastolic Blood Pressure (DBP):

(normally it is 60- 90 mm Hg with average 80 mmHg).

AIR PASSAGE

AIR PASSAGE

1-Conducting Zone (=Dead Space):

- Nose to terminal bronchioles (16 generation)
- The wall of the conducting part is thick, so no gas exchange. Therefore, it called **dead space**.

2- Respiratory Zone:

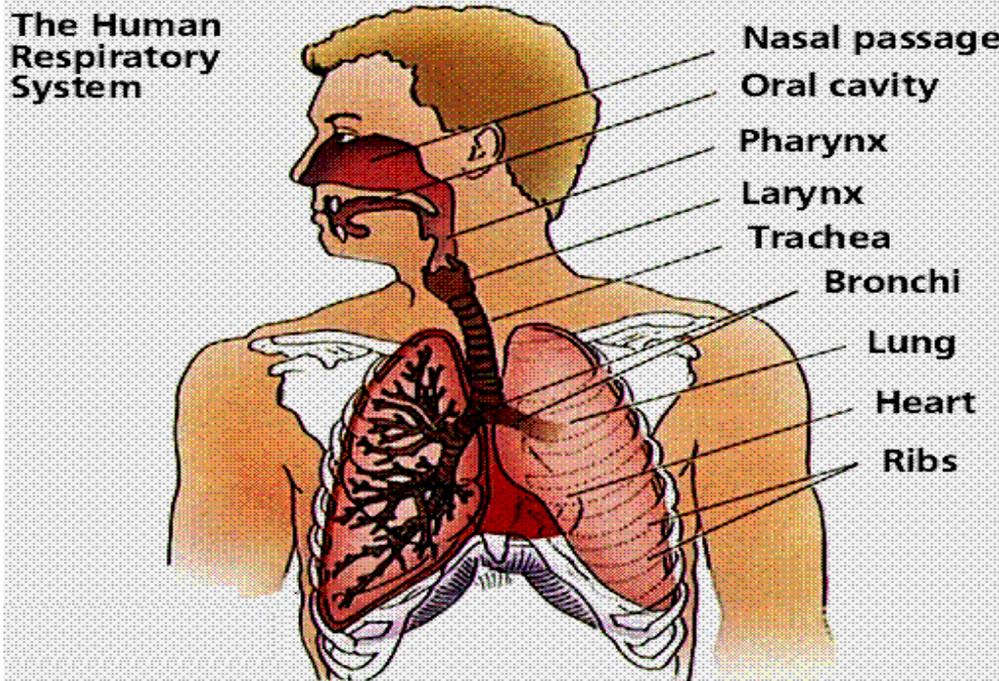
- Respiratory bronchioles to alveoli (17- 23 generations).
- Site for gas exchange (thin wall).
- Air present in it is called **alveolar air**.

		Generation		Diameter cm	Number
Conducting zone	trachea		0	1.80	1
	bronchi		1	1.22	2
			2	0.83	4
	bronchioles		3	0.56	8
			4	0.45	16
			5	0.35	32
terminal bronchioles		16	0.06	6×10^4	
Transitional and Respiratory zones	respiratory bronchioles		17	↓	↓
			18	↓	↓
			19	0.05	5×10^5
	alveolar ducts	T ₃	20	↓	↓
		T ₂	21	↓	↓
		T ₁	22	↓	↓
	alveolar sacs	T	23	0.04	8×10^6

RESPIRATORY SYSTEM

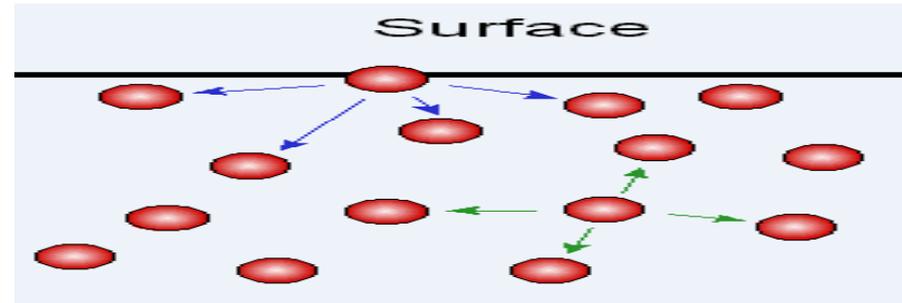
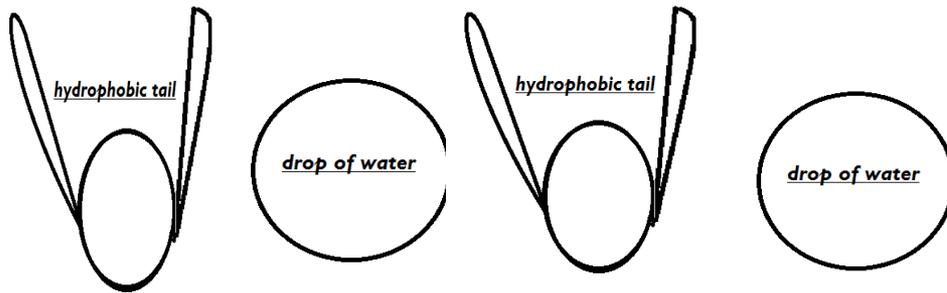
DEFINITIONS

- **Dead space** : It is the volume of air which does not undergo gas exchange with blood in the lung (=150 ml).



	Generation		Diameter cm	Number	
Conducting zone	trachea	0	1.80	1	
	bronchi	1	1.22	2	
		2	0.83	4	
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Respiratory zones	respiratory bronchioles	17			
		18			
		19	0.05	5×10^5	
	alveolar ducts	T ₃	20		
		T ₂	21		
		T ₁	22		
alveolar sacs	T	23	0.04	8×10^6	

- **Elastic Recoil of the Lungs:** When the lung is inflated, it tends to recoil (collapse).
- **Surfactant:** It is a surface active agent secreted by type II alveolar epithelial cell to decrease the surface tension of fluid lining alveoli and antagonist lung collapse.



- **Compliance of the lungs:** A unit change in lung volume per the unit change in distending pressure.

-Normally the walls of alveoli are coated with a thin film of water.

- **Tidal volume:** It is the volume of air that can be inspired or expired during a single breath in resting person.
- **Pulmonary ventilation :** It is the volume of air respired in one minute (by normal respiration). Respiratory rate is normally from 12 beat/ minute. Pulmonary ventilation = tidal volume X respiratory rate. $500 \times 12 = 6000$ ml/minute (6 liters/min).
- **Alveolar Ventilation =Effective Pulmonary Ventilation:**
= (tidal volume – dead space) X respiratory rate
= $500-150 \times 12 = 4200$ ml/minute.
- **Maximum Breathing Capacity (MBC):** It is the maximum volume of air respired in one minute by deepest and fastest respiration = 60 liters/min..

- **Intrapleural pressure:** It is the pressure of the fluid in the pleural cavity.
- **Pneumothorax:** It is the presence of the air in the pleural cavity.
- **Intrapulmonary pressure:** It is the pressure inside the alveoli.
- **Hypoxia :** It is the decreased of O₂ supply or O₂ utilization at the tissue.
- **Dyspnea :** It is awareness of difficulty in breathing.
- **Orthopnea :** This is the difficulty breathing in lying in bed but not in standing or sitting positions due to compression of the diaphragm by the viscera.
- **Apnea :** It is the temporary stoppage of respiration.

CYANOSIS

It is the bluish discoloration of the skin and mucous membrane due to increased amount of reduced hemoglobin above 5 gm % in capillary blood.



RESPIRATORY MUSCLES

I-Muscles of Inspiration: 1-Main Muscles:

A- Diaphragm:- (supplied by the phrenic nerve (origin from C3 to C5). **70%** Contraction (= descent) of the diaphragm leads to enlargement of the thoracic cavity vertically.

B-External Intercostal Muscles: Contraction of them lead to elevation and eversion of the ribs.

2-Accessory Muscles:- Act only in forced inspiration.

-They are sternomastoid (elevates the sternum), scaleri (elevates the 1st rib), seratus posterior superior and seratus posterior inferior (elevate the remaining ribs).

II-Muscles of Expiration:

Expiratory muscles act only in forced expiration.

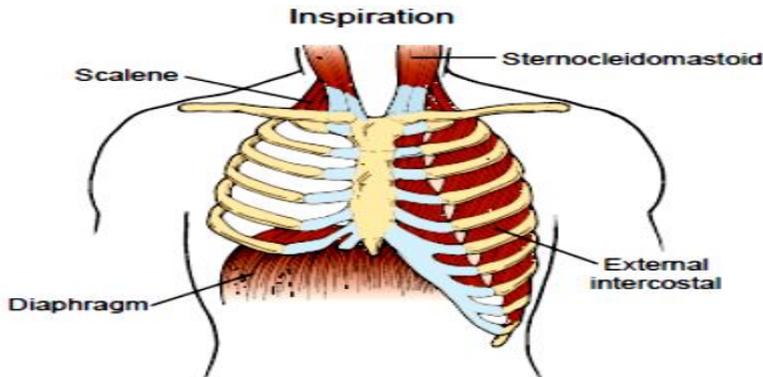
A-Abdominal Wall Muscles:

(i.e. abdominal recti, transverses abdominis, internal and external oblique muscles). Contraction leads to compression of abdominal contents which increases the intra-abdominal pressure and elevates the diaphragm upward.

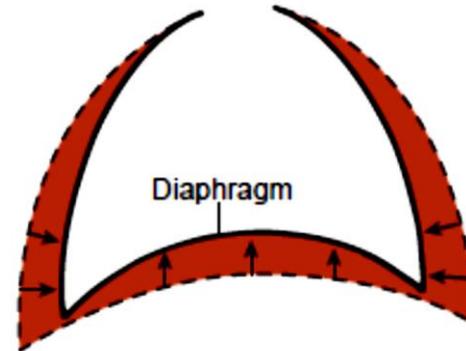
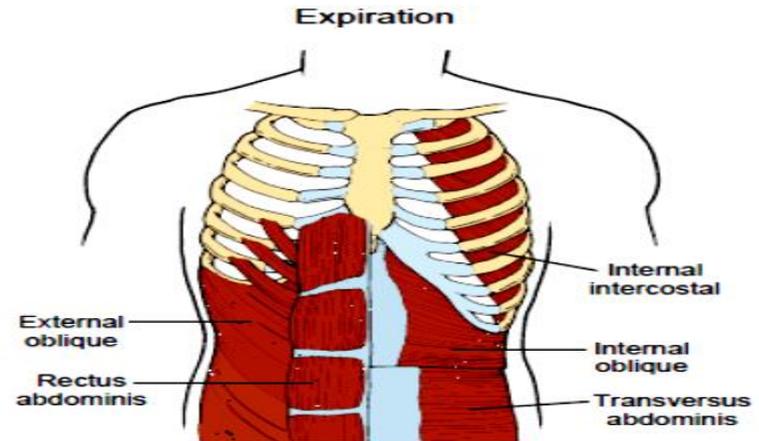
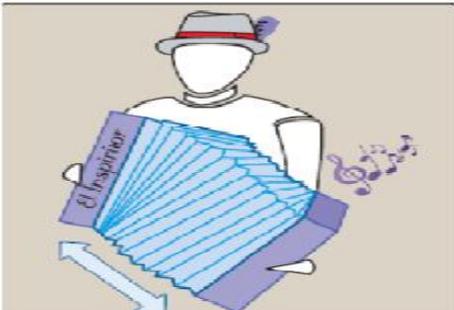
B-Internal Intercostal Muscles:

Contraction of the internal intercostal muscles leads to depression and inversion of the ribs.

RESPIRATORY MUSCLES



daphragm = descend

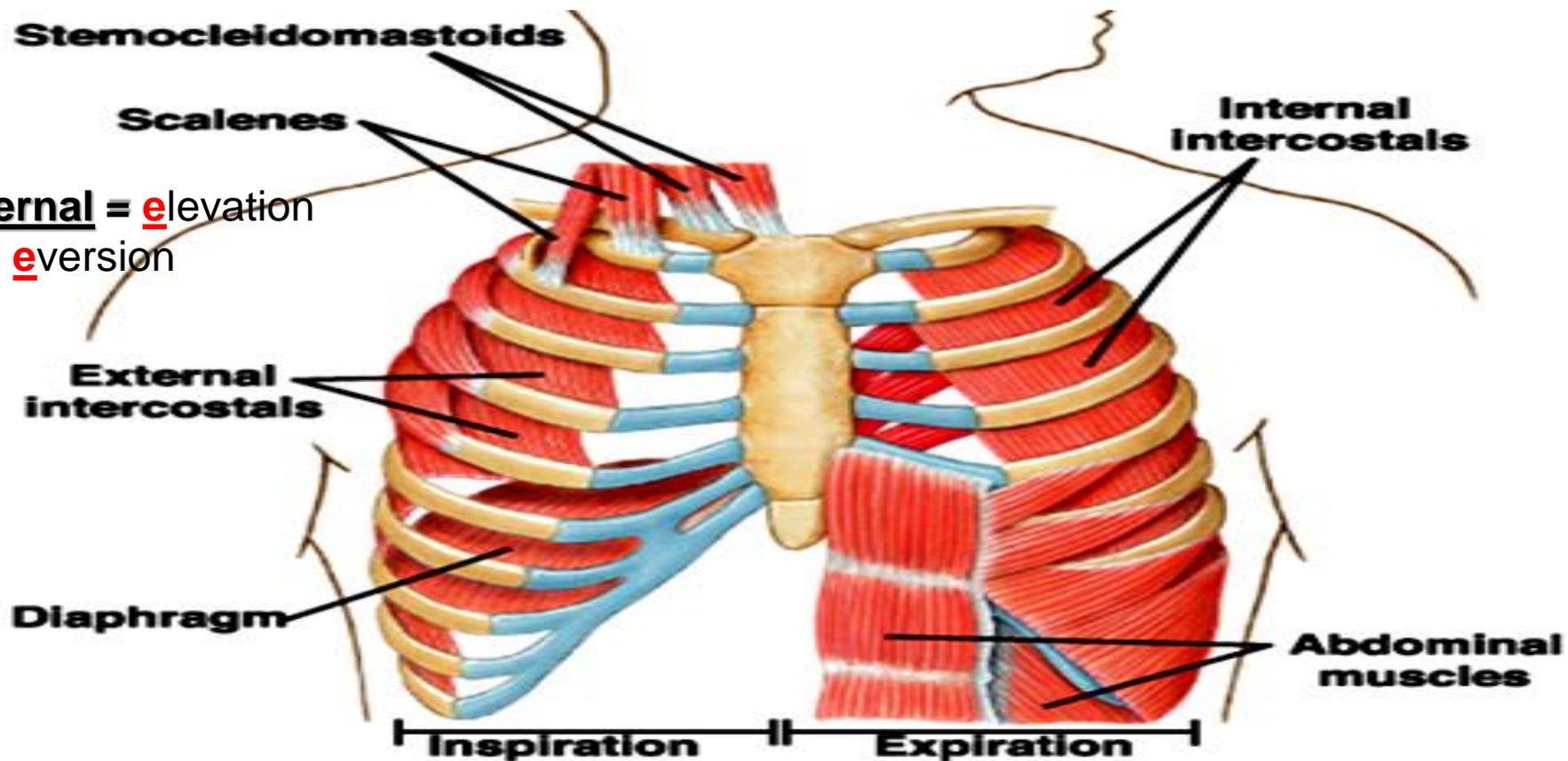


external = elevation and eversion

diaphragm = descend

RESPIRATORY MUSCLES

eexternal = elevation
and eversion



MECHANISM OF BREATHING

1-Inspiration:

A-In Normal Resting Inspiration:

Respiratory center → phrenic and external intercostal nerves → contraction diaphragm and external intercostal muscles → expansion of the chest wall in all directions → distention of the lung and decrease of intrapulmonary pressure to (−1 mm Hg) & rush the air into the lungs.

B- In Forced Inspiration:

The main and the accessory muscles contract strongly so, greater increase in the thoracic cavity and rush more volume to the lungs.

2-Expiration:

A-In Normal Resting Expiration:

-Normal expiration is the passive process. It is produced by relaxation of inspiratory muscles. Drop of the thoracic cage and elevation of diaphragm increase of intrapulmonary pressure to (+1 mm Hg) & rush the air out the lungs.

B- In Forced Expiration:

The expiratory muscles contract strongly so, more depression and inversion of ribs more decrease in the thoracic cavity and rush more volume out of the lungs.