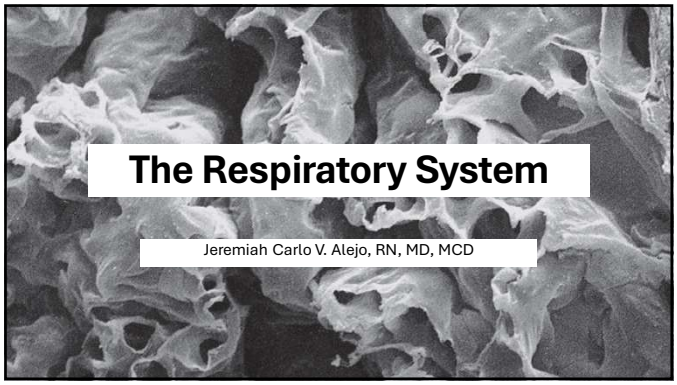


1

Respiration

- Cellular/Internal – series of intracellular biochemical processes by which the cell produces energy by metabolism of organic molecules
- Mechanical Respiration – involves the following steps:
  - Pulmonary Ventilation: inhalation and exhalation
  - External respiration: exchange of gases between the alveoli of the lungs and the blood in pulmonary capillaries across the respiratory membrane
  - Cleaning, warming, and moistening of air

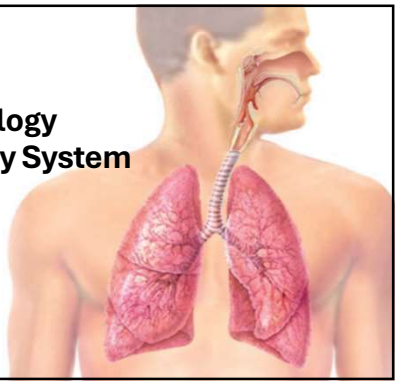
2

Objectives: After the lecture, the students will be able to:

- Describe the anatomy and histology of the parts of the respiratory system
- Explain the function of the structures of the respiratory system
- Describe the events that cause inhalation and exhalation
- Differentiate the lung volumes and capacities
- Describe factors affecting the exchange of oxygen and carbon dioxide
- Explain how the nervous system controls breathing
- Explain how various affects factors affect the rate and rhythm of breathing
- Describe the effects of exercise on the respiratory system
- Describe important developmental changes in the respiratory system

3

Anatomy and Functional Histology of the Respiratory System



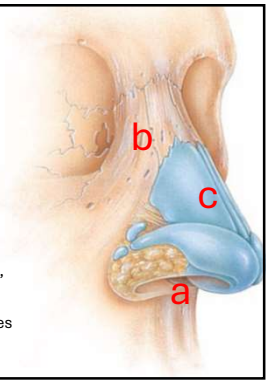
4

Part		Structural Classification	Functional Classification
Nose, nasal cavity and accessories		Upper Respiratory System	Conducting Zone – filter, warm, moisten, and conduct air into the lungs
Pharynx			
Larynx		Lower Respiratory System	
Trachea			
Lungs	Bronchi		
	Bronchioles		
	Terminal Bronchioles		
	Respiratory bronchioles		Respiratory Zone – gas exchange
	Aleveoli		

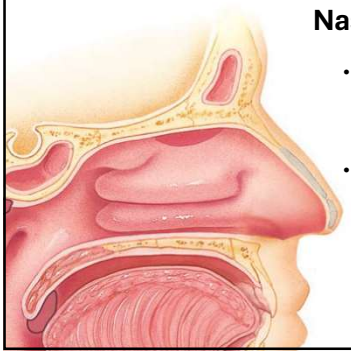
5

Nose

- Functions:
  - Warming, moistening, filtering incoming air
  - Detecting olfactory stimuli
  - Modifying speech vibrations
- External Nose: portion visible on the face
- Parts:
  - External nares (a) – openings
  - Bony framework (b): frontal bone, nasal bones, maxillae
  - Cartilagenous framework (c): septal nasal cartilage, lateral nasal cartilages, alar cartilages



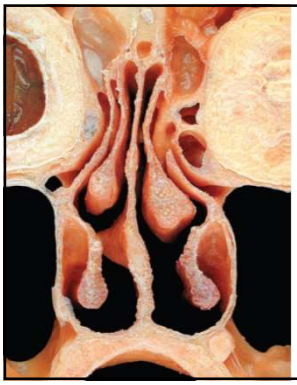
6



Nasal Cavity

- Space in the anterior aspect of the skull inferior to the nasal bone and superior to the oral cavity
- Merges anteriorly with the external nose and communicates posteriorly with the pharynx through the internal nares or choanae

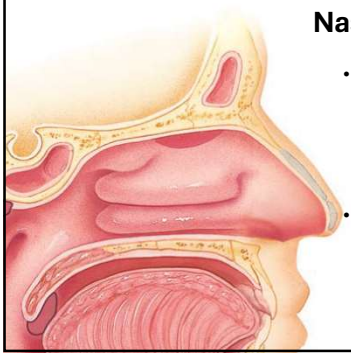
7



Nasal Cavity

- Nasal conchae – form shelves that extend from the lateral walls of the nasal cavity
- Connects with:
  - Paranasal sinuses – produce mucus and acts as resonating chambers
  - Lacrimal ducts

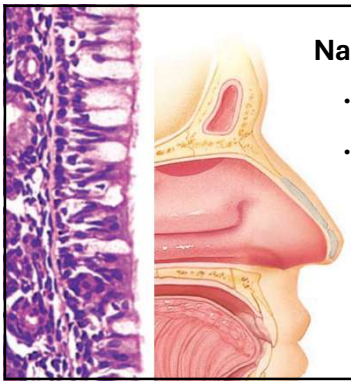
8



Nasal Cavity: Divisions

- **Olfactory Region** – superior
  - Olfactory epithelium – contain olfactory receptor cells , supporting cells, and basal cells
- **Respiratory Region** – inferior

9



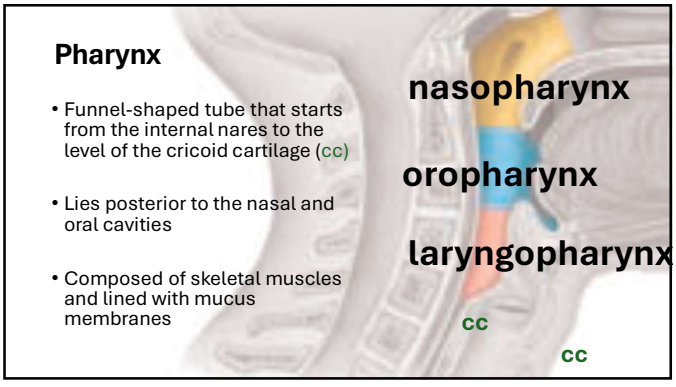
Nasal Cavity: Divisions

- **Olfactory Region** – superior
- **Respiratory Region** – inferior
  - Composed of ***respiratory epithelium***
    - Pseudostratified ***cilia***ted columnar epithelium containing mucin-secreting ***goblet cells***
      - Serous and mucous glands - trap small particles in the inspired air
      - Cilia – propels mucus towards the pharynx

10

Pharynx

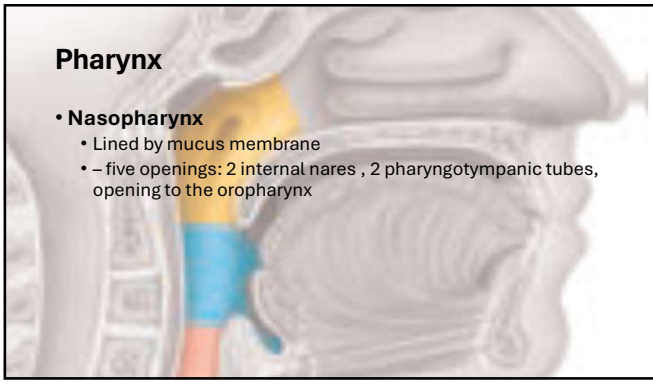
- Funnel-shaped tube that starts from the internal nares to the level of the cricoid cartilage (cc)
- Lies posterior to the nasal and oral cavities
- Composed of skeletal muscles and lined with mucus membranes



11

Pharynx

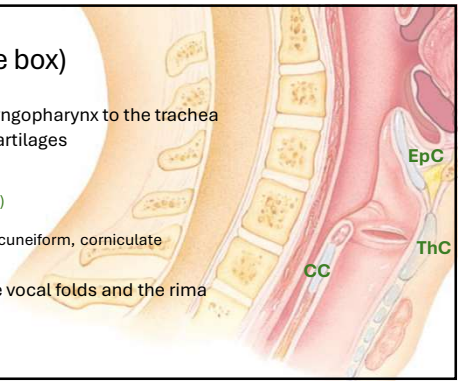
- **Nasopharynx**
  - Lined by mucus membrane
  - – five openings: 2 internal nares , 2 pharyngotympanic tubes, opening to the oropharynx



12

Larynx (voice box)

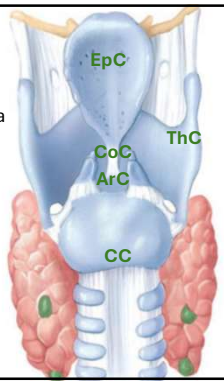
- Connects the laryngopharynx to the trachea
- Composed of 9 cartilages
  - Single:
    - Thyroid (T)
    - Epiglottis (Ep)
    - Cricoid (cc)
  - Pairs: arytenoid, cuneiform, corniculate
- Glottis: pair of the vocal folds and the rima glottidis



13

Larynx (voice box)

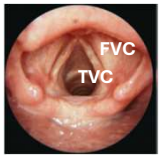
- Connects the laryngopharynx to the trachea
- Composed of 9 cartilages
  - Single: epiglottis, thyroid, cricoid
  - Pairs:
    - Arytenoid (ArC)
    - Cuneiform (CuC
    - Corniculate(CoC)

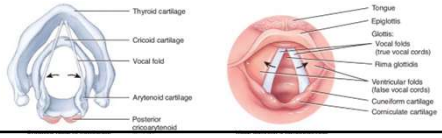


14

Larynx: Voice Production

- 2 folds of mucus membranes:
1. Ventricular folds (false vocal cords) – superior
2. Vocal folds (true vocal cords) – inferior
   - Contracting and relaxing of the intrinsic muscles varies the tension (causing differences in pitch)
   - Sound originates as the vocal folds vibrate
- Resonating chambers: pharynx, mouth, nasal cavity, paranasal sinuses

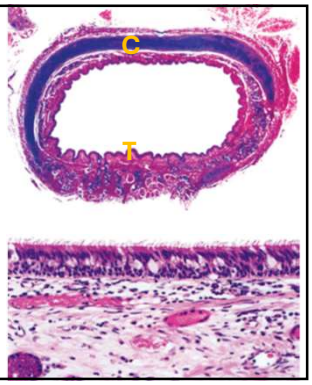




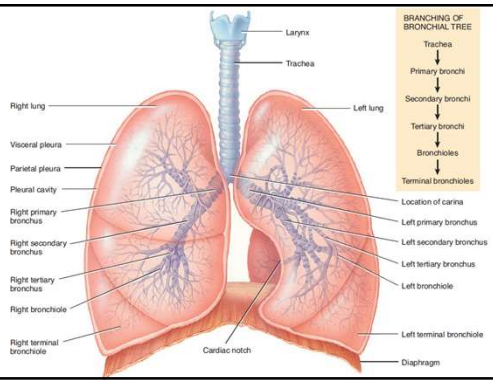
15

Trachea

- Located anterior to the esophagus
- Divides into the right and left primary bronchi at the level of the 5th thoracic vertebra
- 16-20 C-shaped horizontal cartilages (C) – provide semirigid support to maintain patency of the tracheal wall
- Trachealis (T) muscle and connective tissue – change subtly during the inhalation and exhalation



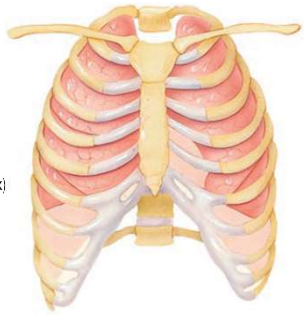
16



17

Lungs

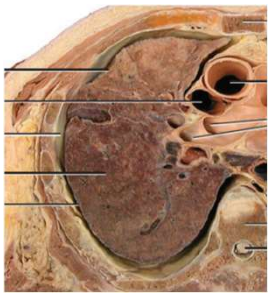
- Paired cone-shaped organs in the thoracic cavity
  - Separated by the heart and other structures of the mediastinum
- Extend from the diaphragm (base) to slightly superior to the clavicles (apex)
- Hilum – entry and exit point of the bronchus, pulmonary blood vessels, lymphatic vessels and nerves



18

Lungs

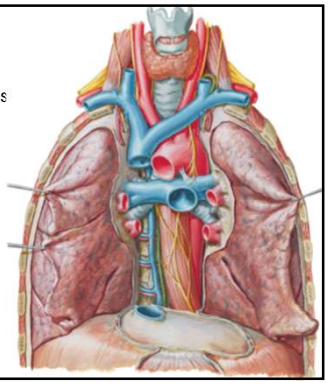
- Pleural membrane – double layered serous membrane enclosing each lung
  - Parietal layer – lines the wall of the thoracic cavity
  - Visceral layer – covers the lung itself
  - Pleural cavity – space containing small amount of lubricating fluid
  - ***Extends about 5 cm below the base of the lungs at the 6th intercostal space anteriorly to the 12th rib posteriorly***



19

Lungs

- Receives blood via 2 sets of arteries
  - **Pulmonary arteries**: delivers deoxygenated blood **from the right side of the heart**
    - Vasoconstrict in response to localized hypoxia to divert circulation to well-ventilated regions for more efficient gas exchange
  - **Bronchial arteries**: delivers oxygenated blood from the aorta to perfuse the muscular walls of the bronchi and bronchioles



20

Bronchial Tree

- Carina: an internal ridge formed by the posterior and inferior projection of the last tracheal cartilage where the trachea divides into the left and right primary bronchi; most sensitive area of the larynx (cough reflex

1. Primary bronchi: Right: more vertical, shorter, and wider
2. Secondary bronchi: one for each lobe
3. Tertiary bronchi
4. Bronchioles
5. Terminal bronchioles – end of the conducting zone
   - Clara cells – columnar nonciliated cells that produce surfactant and function as stem cells

21

Bronchial Tree

- Changes in the structure:

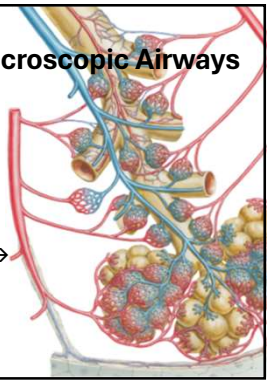
1. Changes from pseudostratified ciliated columnar epithelium to ciliated columnar epithelium with some goblet cells to ciliated simple cuboidal epithelium with no goblet cells to mostly nonciliated simple cuboidal epithelium
2. Incomplete cartilage rings to plates to none
3. Increase in smooth muscles as one goes into the more terminal branches
   - Affected by the autonomic nervous system

22

Lobules of the Lungs and Microscopic Airways

Lung Lobule

- wrapped in elastic connective tissue
- Contains:
  - a lymphatic vessel
  - an arteriole
  - a venule
  - a branch from a terminal bronchiole → respiratory bronchioles → alveoli
    - Change from simple cuboidal to simple squamous epithelial cells



23

Alveoli

- Cup-shaped outpouching of alveolar ducts composed of simple squamous epithelium
- Composed of 2 types of epithelial cells
  - **Type I alveolar cells:** lining of the alveolar wall; ***main sites of gas exchange***
  - **Type II alveolar cells:** septal cells ; secrete alveolar fluid, including ***surfactant***
    - Surfactant, lowers the surface tension of alveolar fluid, preventing alveoli from collapsing
- **Dust Cells** – alveolar macrophages that remove fine dust particles and debris

24

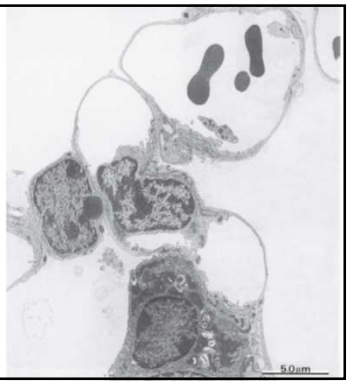
Alveoli

Respiratory membrane

- Site of gas exchange via diffusion

- consists of

1. Alveolar wall
2. Epithelial basement membrane
3. Capillary basement membrane
4. Capillary endothelium



25

Pulmonary Ventilation

26

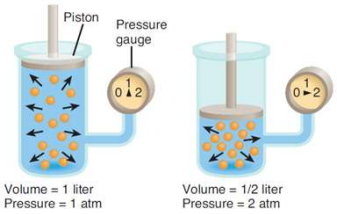
Pulmonary Ventilation

- inhalation (inflow) and exhalation (outflow) of **air**
- involves the exchange of air between the atmosphere and the alveoli of the lungs
- Created by the contraction and relaxation of the respiratory muscles
  - Also influenced by alveolar surface tension, lung compliance, and airway resistance

27

Boyle's Law

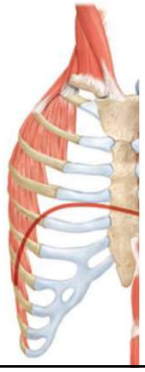
- The pressure of a gas in a closed container is inversely proportional to the volume of the container



28

Inhalation

- For air to flow into the lungs, the pressure inside the alveoli must become lower than the atmospheric pressure: **Lungs expand** to ***increase the volume and decrease the intrapleural and alveolar pressures***
  - *Through the contraction of the main muscles of inhalation: Diaphragm and the external intercostal muscles*

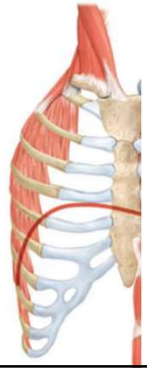


29

Inhalation

Diaphragm - most important muscle of inhalation

- Dome-shaped skeletal muscle that forms the floor of the thoracic cavity
- Innervated by the phrenic nerve (CC 3-5)
- Descends about 1- 10 cm during inhalation

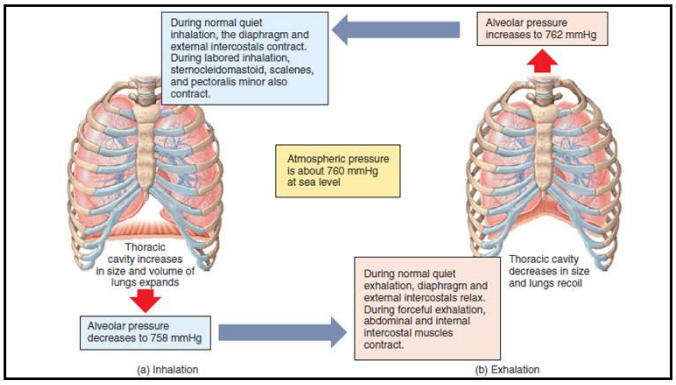


30

Exhalation

- A usually passive process ***resulting from elastic recoil*** of the chest wall and the lungs:
  - Recoil of elastic fibers stretched during inhalation
  - Inward pull of surface tension due to the alveolar fluid
- starts when inspiratory muscles relax (diaphragm moves superiorly, ribs depress with the relaxation of the external intercostal muscles) causing alveolar pressure to increase

31



32

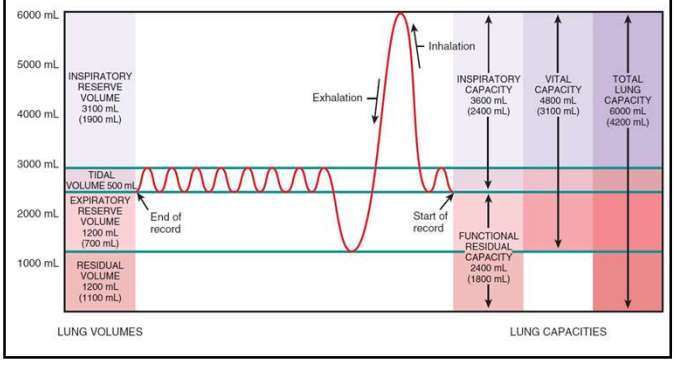
Other Factors Affecting Pulmonary Ventilation

- **Surface Tension** – polar attraction from water molecules in fluid produces an inwardly directed force causing alveoli to assume the smallest possible diameter; reduced by surfactant
- **Lung compliance** – the effort needed to stretch the lungs and chest wall (high compliance means the chest walls and lungs expand easily); related to elasticity and surface tension
- **Airway resistance** – based on size of the airways

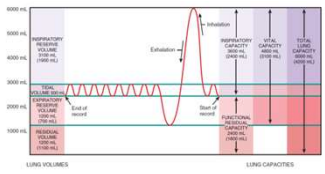
33

Lung Volumes and Capacities

34



35

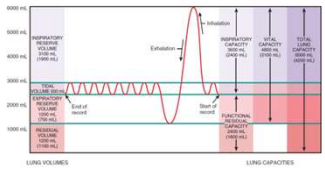


Tidal Volume

- The volume of one breath
- Minute volume – total volume inhaled and exhaled each minute
  - Breaths /min x tidal volume
- Measured by a spirometer or respirometer

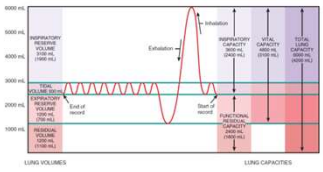
36

Tidal Volume



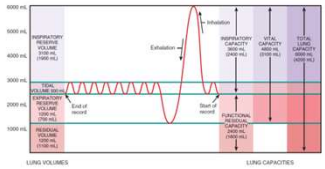
- About 70% actually reaches the respiratory zone
  - Alveolar ventilation rate- volume of air per minute that reaches the respiratory zone
  - 30% remains in the conducting zone (***anatomic dead space:*** airways with air that does not undergo respiratory exchange))

37



- **Inspiratory reserve volume:** additional inhaled air during deep breathing
- **Expiratory reserve volume:** additional volume of air pushed out during forced exhalation
  - FEV1 – forced expiratory volume in 1 second

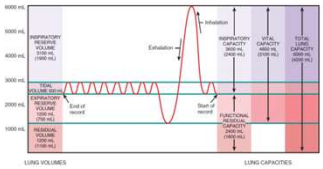
38



- **Residual volume:** amount of air remaining in the lungs even after forced expiration
- **Minimal volume**: air remaining if the residual volume is removed

39

Lung Capacities



Combinations of specific lung volumes

- **Inspiratory capacity =** TV + IRV
- **Functional residual capacity** = RV +ERV
- **Vital Capacity** = IRV + TV + ERV
- **Total Lung Capacity** = VC + RV

40

Gas Exchange

41

Dalton's Law of Gases

- Each gas in a mixture of gases exerts its own pressure

Partial pressure: the pressure of a specific gas in a mixture

- determine the movement of oxygen and carbon dioxide (diffusion from area of greater partial pressure to less)

$$
\begin{aligned}
P_{N_2} &= 0.786 \times 760\ \text{mmHg} = 597.4\ \text{mmHg} \\
P_{O_2} &= 0.209 \times 760\ \text{mmHg} = 158.8\ \text{mmHg} \\
P_{Ar} &= 0.0009 \times 760\ \text{mmHg} = 0.7\ \text{mmHg} \\
P_{H_2O} &= 0.003 \times 760\ \text{mmHg} = 2.3\ \text{mmHg} \\
P_{CO_2} &= 0.0004 \times 760\ \text{mmHg} = 0.3\ \text{mmHg} \\
P_{\text{other gases}} &= 0.0006 \times 760\ \text{mmHg} = 0.5\ \text{mmHg} \\
\text{Total} &= 760.0\ \text{mmHg}
\end{aligned}
$$

42

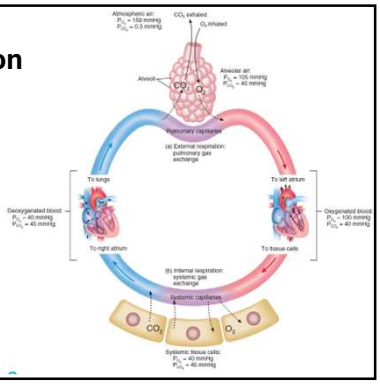
Henry's Law

- The quantity of gas that will dissolve in liquid is proportional to the partial pressure of the gas and its solubility
  - Nitrogen: low solubility in blood
  - In diving: increased partial pressure at sea → nitrogen narcosis and decompression sickness

43

External Respiration

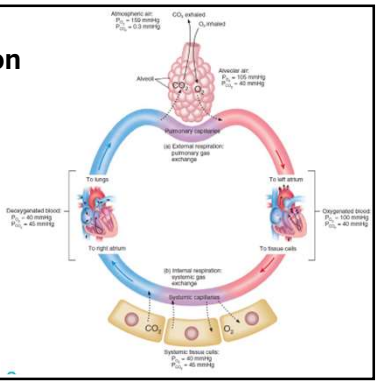
- Pulmonary gas exchange; diffusion of oxygen from air in the alveoli to blood in pulmonary capillaries and the diffusion of carbon dioxide in the opposite direction



44

External Respiration

- Converts deoxygenated blood into oxygenated blood
- Maximal amount of 02 diffusion: large amounts of capillaries and slow flow of blood



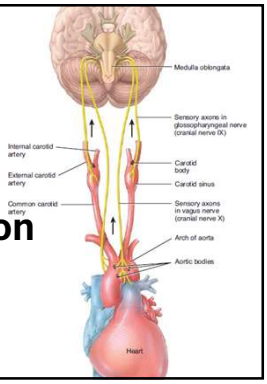
45

Factors Affecting Gas Exchange

- Partial pressure difference of the gases
- Surface area available for gas exchange
- Diffusion distance/membrane thickness
- Molecular weight and solubility of the gas

46

Control of Respiration

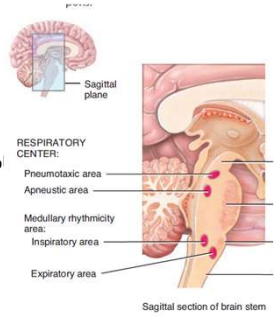


47

Respiratory Center

- Cluster of neurons that alter the action of the respiratory muscles
- 3 areas:

1. **Medullary Rhythmicity Area** - contro the basic rhythm of respiration
   - ***Inspiratory area*** (establishes the basic rhythm) → intercostal nerves (→ external intercostal muscles) and phrenic nerve (→diaphragm)
   - Expiratory area – active during forceful breathing → internal intercostal and abdominal muscles

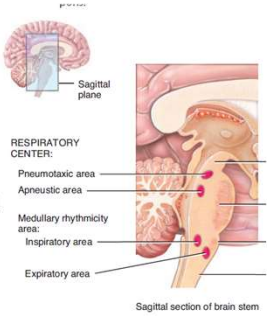


48

Respiratory Center

- Cluster of neurons that alter the action of the respiratory muscles
- 3 areas:

2. **Pneumotaxic area** – transmits inhibitory impulses to the inspiratory area before the lungs fill too much with air
3. **Apneustic area** – sends stimulatory impulses to the inspiratory area

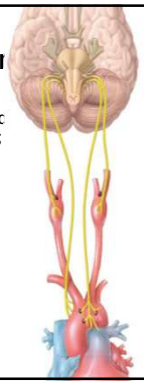


Sagittal section of brain stem

49

Regulation of the Respiratory Center

- **Cortical influences** – voluntary (holding of breath) and involuntary (through emotions) alteration of breathing;
  - Limited due to buildup of carbon dioxide and H+
- **Chemoreceptor Regulation**
  - Central: medulla oblongata detects H+ and CO2 in CSF
  - Peripheral: aortic and carotid bodies
  - EVEN A SLIGHT INCREASE IN PCO2 WILL STIMULATE THE CENTRAL CHEMORECEPTORS → HYPERVENTILATION
  - SEVERE 02 DEFICIENCY DEPRESSES THE CENTRAL CGEMORECEPTORS

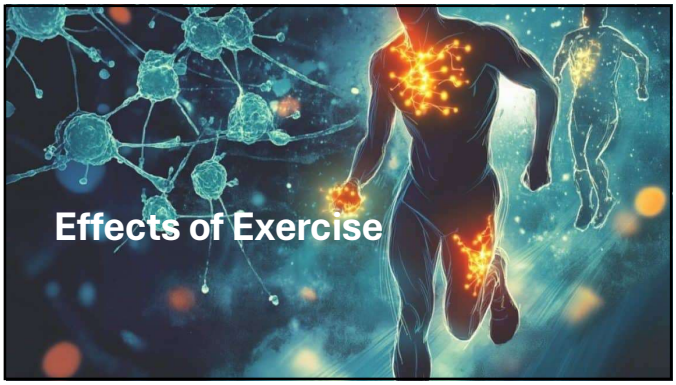


50

Regulation of the Respiratory Center

- **Proprioceptor Stimulation** – movement of joints and muscles stimulate the inspiratory area through proprioceptors
- **Inflation Reflex** - hyperinflation → stretch receptors in the bronchi and bronchial walls stimulated → vagus nerve → inspiratory area inhibition
- Others: limbic system stimulation (emotion), temperature, pain , stretching the anal sphincter, irritation of airways, blood pressure

51



52

Adjustments in the Respiratory System

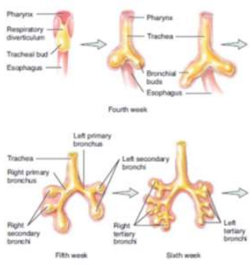
- Increased cardiac output → increased pulmonary perfusion
- Increased oxygen usage → decreased systemic venous oxygen partial pressure → increased oxygen diffusion
- Increase in pulmonary ventilation depth and rate

53

Development of the Respiratory System

54

- 22-26 days after fertilization – respiratory diverticulum (epithelium of the lungs arises as a pouch from the primitive foregut) develops anterior to the pharynx
- Week 16– all major elements have formed except those involved in gas exchange (tracheal buds to bronchial buds)
- Week 24: respiratory bronchioles have developed



55

- Week 26 – primitive alveoli develop; capillaries contact alveoli; surfactant produced
- Week 30 – mature alveoli develop

Others:

- Development of pleural sac from mesoderm
- Breathing movements in-utero –fluid aspiration in the lungs
  - Absorbed by lymphatics once breathing begins at birth

56

Effects of Aging

- Tissues become less elastic and more rigid → decreased lung capacity
- Decreased blood level of oxygen
- Decreased activity of alveolar macrophages and diminished ciliary action of the respiratory epithelium → susceptibility to infection

57

References

Tortora, GJ and Derrickson, B. Anatomy and Physiology, 13th edition. Massachusetts: John Wiley and Sons, Inc. 2013

Young, B, O'Dowd, G, and Woodford, P. Wheater's Functional Histology: A Text and Colour Atlas, 6th Edition. Philadelphia: Elsevier Churchill Livingstone. 2014

58