1. **Respiration is the liberation of chemical energy by the oxidation of food.** The released chemical energy is stored as ATP molecules. Most organisms need O₂ for respiration and release CO₂ as waste product. Respiration takes place inside cells. Glucose +6 O₂ → 6CO₂ + 6H₂O + ATP (energy). It means tissues consume O₂ and generate CO₂.

2. Functions of Respiratory System:
   - Supplies O₂ and removes CO₂
   - Joins kidney to Regulate pH of blood
   - Produces sounds for speech
   - Defends against microbes

3. **Human Respiratory System:** Has 3 portions:
   - **Upper Airways:** external nares → nasal cavity → nasopharynx → oropharynx → laryngopharynx → larynx
   - **Conducting zone:** trachea → bronchi → bronchioles → terminal bronchioles
   - **Respiratory Zone:** respiratory bronchioles → alveolar ducts → alveoli (main portion of gas exchange)

4. **Conducting Zone**
   - Provides a low resistance path to alveoli
   - Bronchioles are the main site of air flow regulation by ANS and hormones. Bronchodilation (expansion of bronchioles) increases ventilation and bronchoconstriction (narrowing of bronchioles) decreases it.
   - Macrophages, mucous and cilia lining it defend against microbes and harmful particles
   - In chronic smokers cilia get damaged leading to mucous accumulation and chronic coughing

5. **Table 22.1:** gives a to the point account of structure and function of all respiratory organs.

6. **The upper respiratory tract:** is shown in fig 15.2 or 23.1.

7. **Nasal Cavity:** Nostrils lead to nasal cavity. Note the 3 conchae in the side walls of nasal cavity – can also observe in skull. Mucous membrane covers them. Mucous and hair help to trap microbes and particles; moisten and warm the air.

8. **3-parts of Pharynx:** 1. Nasopharynx – the superior part, nasal cavity opens into it 2. Oropharynx – is the middle part at the back of mouth/buccal cavity where food and air cross paths 3. Laryngopharynx – inferior part that leads to larynx. Pharynx is a common passage for food and air.

9. **Larynx = the sound box:** is supported by 8 cartilages. **Thyroid** – is large shield like, curved cartilage that forms the front and side walls of larynx. **Cricoid** – is another single cartilage; it is 2nd largest cartilage in larynx; is ring like anteriorly narrow but broad posteriorly, lies inferior to thyroid. 3 pairs of cartilages are present in larynx. Most important is **Arytenoid Cartilages.** Most laryngeal muscles get attached to this pair and move them. In turn these arytenoids cartilages move the true vocal cords that produce the sound. Fig 15.4

10. **Epiglottis** is superior extension of thyroid and is covered with epithelium. It guides food and air to esophagus and larynx.

11. **Glottis** is the gap between the true vocal cords. False vocal cords lie lateral to true vocal cords.

12. **Pitch of Sound** – Larynx produces high pitch sounds when glottis is narrow and low pitch deep sounds when glottis is wide. Fig 15.4. The **volume of the sound** is controlled by regulating the amount of air forced out through glottis.

13. **Trachea = Windpipe:** lies anterior to food pipe, esophagus. It has incomplete C-shaped cartilages to make its wall non-collapsible. Trachea inferiorly divides into Bronchi.

14. **Bronchi** enter lungs. Left lung has 2 lobes and right lung has 3 lobes. Each primary bronchus entering respective lung divides into secondary bronchi that carry air to different lobes. Secondary bronchi divide into tertiary bronchi that carry air to different segments of lobes. The bronchi divide further divide and have cartilaginous rings to support them. Ultimately they produce fine tubes without rings – Bronchioles.

15. Primary bronchus → secondary bronchus → tertiary bronchus → terminal bronchioles → respiratory bronchioles → alveolar ducts → alveoli.
16. **Respiratory zone**: It consists of respiratory bronchioles, alveolar ducts and alveoli. Main site of exchange of gases is Alveoli = air sacs. Each alveolus is surrounded by large # of pulmonary capillaries. Gases need to pass through 1 layer of very flat alveolar cells and 1 layer of endothelium of capillary wall
   - Type 1 Alveolar cells: very flat form main wall
   - Type 2 Alveolar cells: are thick cells and secrete detergent like Surfactant that keeps alveoli noncollapsible.

17. **Respiratory Physiology** has 4 main Phases. A) Breathing or Pulmonary Ventilation B) External Respiration – exchange of gases between lungs and blood C) transport of gases in blood D) Internal Respiration - exchange of gases between blood and tissues. Fig 22.9. Structure of human respiratory system is well documented in Fig 15.1 or Fig23.1 - 2.

18. **Breathing or Pulmonary Ventilation**: 2 Phases of Breathing are Inspiration and Expiration. Fig 15.10. When air enters the lungs it is inhalation and when it leaves the body it is exhalation. During inspiration rib cage moves up and out and diaphragm, a muscular sheet, moves down. It reduces pressure around lungs. As a consequence Lungs expand. During expiration rib cage moves down and in and the diaphragm moves up. The respiratory route air passes through is: Nostrils ➔ nasal cavity ➔ Pharynx ➔ Larynx ➔ Trachea ➔ Bronchi (with cartilaginous rings) ➔ Bronchioles (without rings) ➔ Alveoli (air sacs). Nasal cavity is lined with hair and mucus which help to clean air.

19. **External Respiration**: Alveoli are the seat of exchange of O₂ / CO₂ between lungs and blood. O₂ from its higher concentration in alveoli moves to blood and CO₂ from its higher concentration in blood moves to alveoli. Both gases move by diffusion. Fig 15.12.

20. **Regulation of breathing**: Breathing is regulated by respiratory centers present in Brain Stem. The center is more sensitive to changes in CO₂ concentration than O₂ concentration. 70% stimulus is the pH of cerebrospinal fluid – directly affected by CO₂ concentration. 30% stimulus is regulated by impulses from receptors inside Carotid and Aortic bodies. Fig 15.16.

21. **Gas transport in blood**: Oxygen – 97% of O₂ binds with hemoglobin inside RBC's and travels as Oxyhemoglobin. 3 % oxygen travels dissolved in plasma. Carbon Dioxide – Most of CO₂ enters RBC's and joins with water to form Carbonic Acid. Carbonic acid ionizes to form H⁺ and HCO₃⁻ ions. Then most HCO₃⁻ = bicarbonate ions enter plasma and travel as sodium bicarbonate. Some CO₂ molecules combine with hemoglobin and travels as Carbaminohemoglobin. Some CO₂ travels physically dissolved in plasma. Fig 15.13 and 15.14

22. **Internal Respiration**: Blood-tissue gas exchange: Pulmonary veins carry O₂ to heart and arteries carry O₂ to body tissue via blood capillaries with thin walls. O₂ enters interstitial fluid and finally into cells. Mitochondria use O₂ and produce CO₂ which leaves cells and enters into blood capillaries through interstitial fluid. Capillaries join to form veins which carry CO₂ to heart which sends the blood to lungs for gas exchange. Fig 15.14

23. **Lung volumes and Capacities** are recorded in fig 15.11. **Residual Volume** is the air in lungs present at the end of a forceful expiration (we cannot empty the lungs). It is about 1200mls. **Tidal Volume** is about 500mls inspired and expired during relaxed Quiet breathing. **Expiratory Reserve Volume** is 1200mls, the air we can expire after tidal expiration. **Inspiratory Reserve Volume** is 3500mls and is the air forcefully inspired in after tidal inspiration. **Vital Capacity** of lungs = Inspiratory Reserve Volume + Tidal Volume + Expiratory Reserve Volume (4.7L) **Total Lung Capacity** = Vital Capacity + Residual Volume (5.9L) All lung volumes vary from person to person

24. **Lung disease**: SO₂ sulfur dioxide, CO carbon monoxide and O₃ like pollutants damage lungs but the worst is tobacco smoke which carries more than 4000 chemicals attached to smoke particles. Many of these molecules are toxic and others are carcinogenic = cause cancer. So lung cancer is more common in smokers than non-smokers. In addition tobacco smoke inactivates cilia lining the lung passages so that harmful particles remain in lungs and make alveoli inelastic. This enlargement of alveoli due to broken walls and loss of elasticity is called **Emphysema**. **Chronic Bronchitis** is the constant irritation of lungs by inhaled irritants and leads to formation of excessive mucus and is the cause of smoker’s cough.