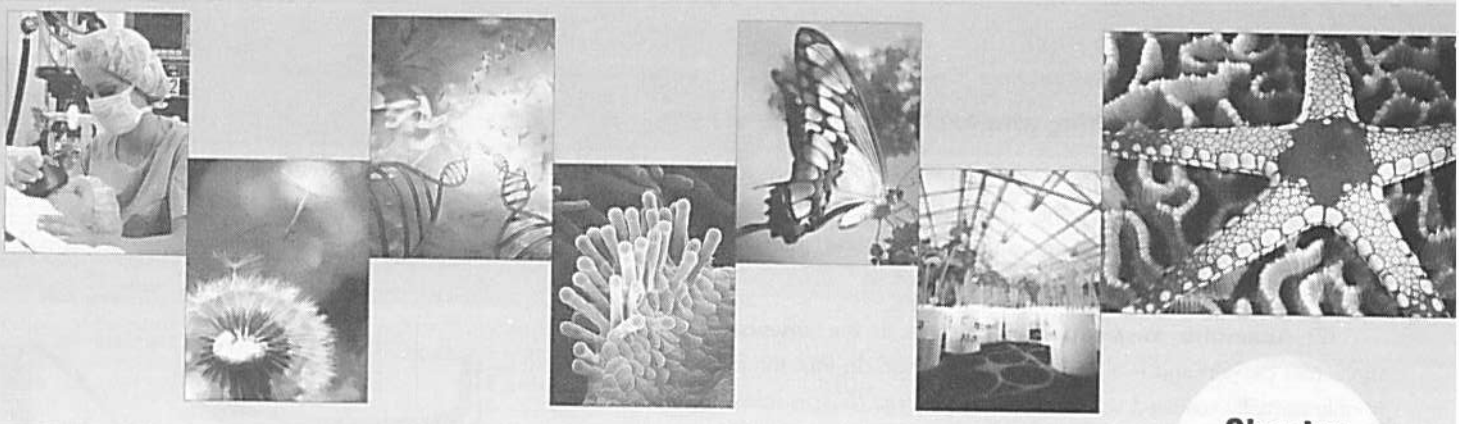


Chapter

5.2

Breathing and Exchange of Gases

Cells continually use oxygen (O_2) for the metabolic reactions that release energy from nutrient molecules and produce ATP (Adenosine Tri Phosphate). At the same time, these reactions release carbon dioxide. Since an exce amount of CO_2 produces acidity that is toxic to cells, the excess CO_2 must be eliminated quickly and efficiently. The two systems that cooperate to supply O_2 and eliminate CO_2 are the cardiovascular system and the respiratory system. The respiratory system provides for gas exchange, intake of O_2 and elimination of CO_2, whereas the cardiovascular system transports the gases in the blood between the lungs and body cells.

Respiration

Respiration is a process which involves intake of oxygen from environment and deliver it to the cells. It include stepwise oxidation of food in cells with incoming oxygen, elimination of CO_2 produced in oxidation, *release of energy during* oxidation and storing it in the form of ATP. It takes place in three basic steps –

(1) **Pulmonary ventilation :** The first process, pulmonary (*pulmo* = lung) ventilation, or breathing, is the inspiration (inflow) and expiration (outflow) of air between the atmosphere and the lungs.

(2) **External (pulmonary) respiration :** This is the exchange of gases between the air spaces of the lungs and blood in pulmonary capillaries. The blood gains O_2 and loses CO_2.

(3) **Internal (tissue) respiration :** The exchange of gases between blood in systemic capillaries and tissue cells is known as internal (tissue) respiration. The blood loses O_2 and gains CO_2. Within cells, the metabolic reactions that consume O_2 and give off CO_2 during production of ATP are termed cellular respiration.

Respiratory surface

The surface at which exchange of gases (CO_2 and O_2) takes place is called respiratory surface. Respiratory surface must be vascular and have enough area for gas exchange. For example – plasma membrane in protozoa, body wall (skin) in annelids, alveocapillary membrane in men.

Respiratory medium

Oxygen is dissolved in air and water. Thus water and air are source of oxygen for animals and called respiratory medium. Water and air are external respiratory medium. Inside the body an internal respiratory medium is also found. This internal respiratory medium is tissue fluid.

Types of respiration : It is of two types

(1) **Aerobic respiration :** It occurs in the presence of molecular oxygen. The oxygen completely oxidizes the food into carbon dioxide and water, releasing large amount of energy. The organisms showing aerobic respiration, are called aerobes. It is found in most of animals and plants. Aerobic respiration is of two main types direct and indirect.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2} \rightarrow \underset{\text{Carbon dioxide}}{6CO_2} + \underset{\text{Water}}{6H_2O} + \underset{\text{Energy}}{2830\,kJ}$$

(i) **Direct respiration :** It is the exchange of environmental oxygen with the carbon dioxide of the body cells without special respiratory organs and without the aid of blood. It is found in aerobic bacteria, protists, plants, sponges, coelenterates, flatworms, roundworms and most arthropods.

(ii) **Indirect respiration :** It involves special respiratory organs, such as skin, buccopharyngeal lining, gills and lungs, and needs the help of blood. The respiration in the skin, buccopharyngeal lining, gills and lungs is respectively called cutaneous buccopharyngeal, bronchial and pulmonary respiration. Cutaneous respiration takes place in annelids, some crustaceans, eel fish, amphibians and marine snakes. It occurs both in water and in air. Buccopharyngeal respiration is found in certain amphibians such as frog and toad. It occurs in the air. Bronchial respiration is found in many annelids, most crustaceans and

molluscs, some insect larvae, echinoderms, all fishes and some amphibians. It occurs in water only. Pulmonary respiration is found in snails, pila, some amphibians and in all reptiles, birds and mammals. It takes place in air only.

(2) **Anaerobic respiration :** It occurs in the absence of molecular oxygen and is also called fermentation. In this, the food is only partially oxidised so only a part of energy (5%) is released and of energy remains trapped in the intermediate compounds. It is found in lower organisms like bacteria and yeast. It is also found in certain parasitic worms (*Ascaris, Taenia*) which live in deficient medium. The organism showing anaerobic respiration, are called anaerobes. These involve one of following reactions.

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow[\text{(Fermentation of sugars)}]{\text{In yeasts}} \underset{\text{Ethanol}}{2C_2H_5OH} + 2CO_2 + 118\,kJ$$

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{In intestinal worms}} \underset{\text{Lactic acid}}{2CH_3CHOHCOOH} + \text{Energy}$$

Certain body tissues of even aerobes also show anaerobic metabolism *e.g.*, during the vigorous contraction of skeletal muscle fibres. In this, the glucose is metabolised into the lactic acid in anaerobic conditions. The rapid formation and accumulation of lactic acid are responsible for muscle-fatigue. The mammalian RBCs shows anaerobic respiration as these lack the mitochondria. In lens of eye and cornea of eye respiration is anaerobic because these structures are non vascular. Anaerobic respiration appeared first in primitive organisms because there was absence of O_2 in primitive atmosphere.

Respiratory organs

(1) **Skin :** Respiration by skin is called cutaneous respiration. Skin is the only respiratory organ in most annelids (earthworm and leeches) and an additional respiratory organ in amphibians (Toads and frogs). Skin should be thin, moist, naked, permeable and well vascular for respiration. For cutaneous respiration animal should have large surface area then its volume and should have relatively inactive life to minimize the use of oxygen. Some marine annelids such as sandworms (nereis) have parapodia (locomotory appendages) for respiration. In frog 100% cutaneous respiration during hibernation. In all marine snakes 20% respiration by skin.

(2) **Tracheae :** In insects, peripatus centipedes and millipedes tracheae are found for respiration. Tracheae are complex system of whitish, shining, intercommunicating air tubules. Tracheae are ectodermal air tubes. In cockroaches, three pairs of longitudinal tracheal trunks are present all along the length of body which are further connected with each other with the help of transverse branches. The main tracheae give off smaller tracheae whose branch repeatedly form a network of trachioles throughout the body. Trachea internally lined by chitinous cuticle called intima, which spirally thickened to form taenidae. Trachioles without taenidae, trachioles lined by trachein protein. From each tracheal trunk three branches come out. The dorsal branch is supplied to the dorsal muscles where as ventral one to nerve cord and ventral muscles and middle one to the alimentary canal.

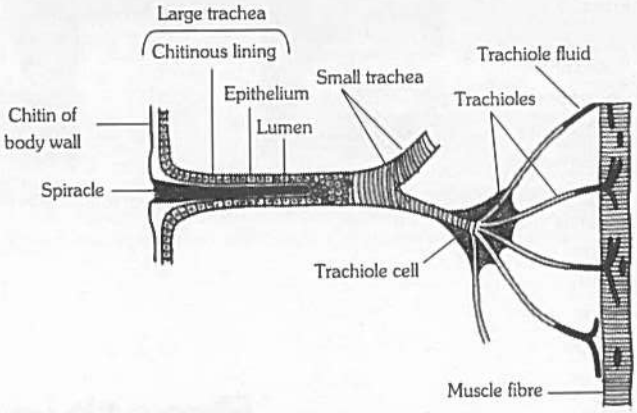


Fig : 5.2-1 Trachea of cockroach

(3) **Book lungs and book gills :** Spiders ticks, mites and scorpion (belongs to class arachnida) have book lungs for respiration. In scorpion 4 pairs of book lungs are present. A book lung is a chamber containing a series of thin vascular, parallel lamellae arranged like the pages of book. Book gills are found in marine king crab or horse shoe crab.

(4) **Gills :** Aquatic animals such as prawn, unio, fishes, sea stars and tadpoles respire by gills. Respiration by gills called bronchial respiration. Gills are of two types –

(i) **External gills :** External gills are found in arenicola (lug worm), larvae of certain insects *e.g.* damsel fly and some amphibians *e.g.* necturus, siren, proteus, frog tadpole first develop external gills which are replaced by internal gills later.

(ii) **Internal gills :** The internal gills may be phyllobranch (prawn), monopectinata (pila) eulamellibrach (unio), lamellibranch, fillibranch (pisces). In all fishes, gills are hemibranch or demibranch and holobranch. In gills, gill lamellae are found which have capillary network. Water is drawn into gills → blood flowing in the capillaries of gill lamellae absorb oxygen from water and release CO_2 → water containing CO_2 is thrown out from gills. The 80% of O_2 of incoming water is absorbed.

Table : 5.2-1 Oxygen content of respiratory media

Respiratory media	Oxygen content
Air	209.5 *ml./l.*
Fresh water at 25°C	5.8 *ml./l.*
Fresh water at 5°C	9.0 *ml./l.*
Sea water at 5°C	6.4 *ml./l.*

(5) **Buccopharyngeal lining :** Frog breathes by buccopharyngeal lining of buccopharyngeal cavity. This is called buccopharyngeal respiration.

Table : 5.2-2 Respiratory organs of animals

Animals	Respiratory organs
Protists, Bacteria	Direct respiration through plasma membrane
Porifera	Plasma membrane of each cell
Coelenterates	General body surface
Platyhelminthes (*Fasciola hepatica*, tapeworm)	Anaerobic
Nematodes (*Ascaris*)	Anaerobic
Annelids (Earthworm and Leeches)	Skin
Nereis	Parapodia
Insects	Trachea
Centipedes	Trachea
Millipedes	Trachea
Spider and Scorpion, ticks, mites	Book lungs
Marine king crab	Book gills
Prawns, Unio and Pila	Gills
Echinodermata	Dermal branchiae, Tube feet, Respiratory tree, Bursae
Fishes, Tadpoles	Gills
Frogs, Toads	Buccopharyngeal lining, Lungs, Skin
Reptiles, Mammals	Lungs
Birds	Air sacs/Lungs
Lung fish	Air bladder.
Urochordata (*Herdmania*)	Test
Marine turtle	Clocal respiration
Mollusca (Unio)	Mental

Respiratory system of human

Human respiratory system is derived from endoderm. Human respiratory system may be divided into two components –

(1) Respiratory tract or conducting portion

(2) Respiratory organs

(1) **Respiratory tract or conducting portion :** It is the passage for the air. In this part gaseous exchange does not takes place. It is also called dead air space. It is divided in following parts –

(i) **Nose** (Latin-*Nasa*) (Greek-*Rhine*) : Cavity of nose is called nasal cavity. Nasal cavity is divided into two parts by nasal septum called mesethmoid. Each part is called nasal chamber. Each nasal chamber opens out side by external nares. Nasal septum has two part. First part is small and is made of cartilage (hyaline). Second part is major and it is bony. Vomer is the main bone. Each nasal chamber has three region.

(a) **Vestibular region :** Vestibular region also known as vestibule is lined by non keratinized squamous epithelium, it is ectodermal in origin and have sebaceous gland, sweat gland and hair. Vestibule is also found in inner air larynx, mouth and vagina. It acts like a seive to check the entry of large dust particles and other things.

(b) **Respiratory region :** Middle region lined by respiratory epithelium which is ciliated pseudostratified columnar epithelium. It contains mucus and serous cells. Mucus cells produce mucus and serous cells produce watery fluid. Respiratory epithelium is highly vascular and appears pink or reddish. Respiratory region acts as a air conditioner and makes the temperature of in going air nearly equal to body. It also acts as a filter not give entry to dust particles, flies or mosquitoes.

(c) **Olfactory region :** It is upper region. It is lined by olfactory epithelium. This is also called Schneiderian epithelium. Olfactory region is the organ of smell and detect the odour of inspired air. Inspiration is stopped if odour of air is foul or offensive. According to new researches pheromone receptors are found in nasal cavities.

(ii) **Nasal conchae :** Lateral wall of nasal cavity have three shelves like structures called conchae or turbinate. 3 pairs of nasal conchae are found. Nasal conchae are covered with mucus membrane. They increase the surface of nasal chamber. Both the chambers of nasal cavity open into nasopharynx by their apertures called internal nostrils or conchae. Adjacent to internal nostril there are opening of eustachian tube. Names of these three conchae and names of the bones that form them are given below.

(a) **Superior conchae** : The dorsal most chochae is supported mainly by nasal bone called nasoturbinate. It is the smallest conchae.

(b) **Middle conchae** : Ethmoid bone called ethmoturbinate.

(c) **Inferior conchae** : The ventral most conchae supported by maxilla bone called maxilloturbinate. It is a separate bone itself.

(iii) **Pharynx :** It is the short vertical about 12 *cm* long tube. The food and air passages cross here. It can be divided in 3 parts –

(a) **Nasopharynx :** Nasopharynx is only respiratory upper part in which internal nares open. There are 5 opening in its wall; two internal nares, two eustachian tube opening and one opening into oropharynx.

(b) **Oropharynx :** Middle part is called oropharynx. In this part oral cavity open known as fauces. Two pair tonsils the palatine and lingual tonsils are found in the oropharynx.

(c) **Laryngopharynx or hypopharynx :** Lowest part is called laryngopharynx. It leads into two tubes. One at the front is wind pipe or trachea and one at the back is food pipe or oesophagus. Both oro and laryngo pharynx is both a respiratory and a digestive pathway.

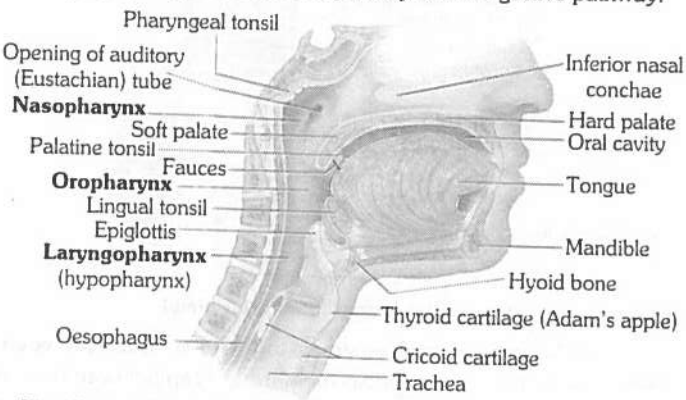


Fig : 5.2-2 Sagittal section showing the regions of the pharynx

Nasopharynx is lined by ciliated pseudostratified epithelia, oropharynx and laryngopharynx are lined by non keratinized epithelium. Pharynx is lined by non keratinized stratified squamus epithelium. This epithelium is cillieted in nasopharynx. Mouth serves as an alternate route for air when nasal chambers are blocked. Foramen by which pharynx opens into larynx called

glottis. In general it remains open. During swallowing it is closed. It provides passage for air. Pharynx leads into the oesophagus through an aperture called gullet. In general condition it remains closed and opens at the time of swallowing. During swallowing epiglottis closes the glottis.

(iv) **Larynx or Voice box :** It is found both in frogs and rabbits. Larynx does not help in respiration. It is present on tip of trachea and is made up of 9 cartilages such as thyroid (single) has a prominence called pomum admi or adam's apple, cricoid (single), arytenoid (paired), are piece of hyaline cartilage. While epiglottis (single), carniculate (paired), cuneiform (paired), santorini are piece of elastic cartilage. Clinically, the cricoid cartilage is the landmark for making an emergency air way.

Larynx is a short tubular chamber and opens into the laryngopharynx by a slit like aperture called glottis. Glottis always remains open except during swallowing. Larynx is more prominent in men than women due to male hormone. Before puberty, the larynx is inconspicuous and similar in both sexes. Larynx is a voice producing instrument. For this purpose larynx have two types of vocal cord. In birds voice producing organ is syrinx, found at lower end of tracheae.

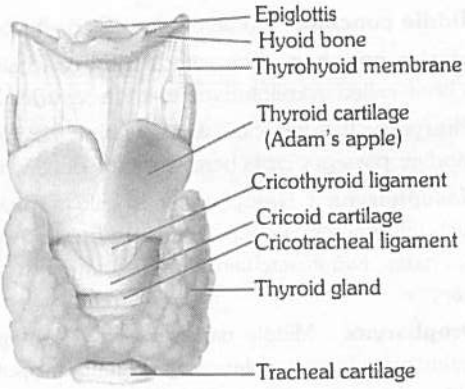


Fig : 5.2-3 Larynx (Anterior view)

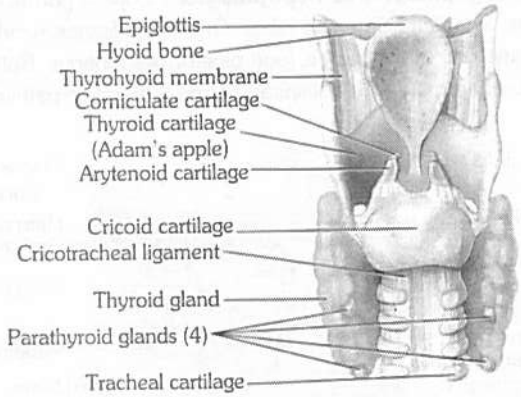


Fig : 5.2-4 Larynx (Posterior view)

(a) **False vocal cord or vibrating fold or anterior vocal cord :** These are folds of mucus membrane. Gap between them is called rema vestibuli. These are not responsible for sound production. In elephants only true vocal cords are present and are responsible for this trumpet sound.

(b) **True vocal cord or posterior vocal cords :** They are made up of yellow elastic fibres. Gap between them is called rema glottides or peep hole. In males the length of true vocal cord is 2.25 *cm* and in female is 1.75 *cm*. Sound produced by rabbit is called quaking. Hippopotamus lacks true vocal cords. Pitch is controlled by the tension of vocal folds.

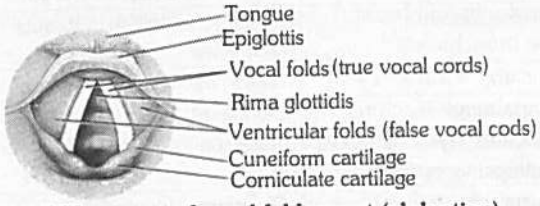


Fig : 5.2-5 Movement of vocal folds apart (abduction)

Fig : 5.2-6 Movement of vocal folds together (adduction)

(v) **Trachea :** It is a tubular structure of about 12 *cm.* in length and 2.5 *cm* in diameter. The wall of trachea is made of fibres, cartilage muscles and the mucus membrane. In middle of thorax at the level of 4th and 5th thoracic vertebra divides it into two branches called right and left primary bronchi. Further division of primary bronchi is given in form of arrow diagram.

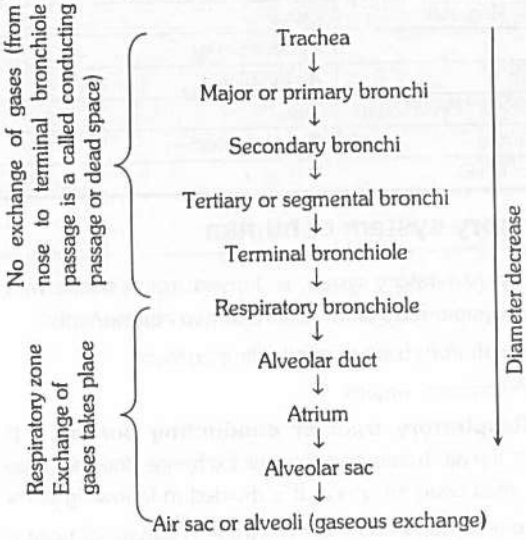


Table : 5.2-3 Different epithelium lining in respiratory tract

Vestibular region of nose	Skin having hair
Respiratory region of nose	Ciliated pseudostratified
Olfactory region of nose	Olfactory (Schneiderian) epithelium
Pharynx (Oropharynx, Laryngopharynx)	Non-keratinised stratified squamous
Trachea and bronchi (Upper)	Pseudostratified ciliated columnar epithelium with mucus cells
Lower bronchi (Secondary / Tertiary)	Lined by simple ciliated columnar epithelia
Terminal bronchioles and beginning of respiratory bronchiole	Simple ciliated columnar epithelium without mucus cells
Rest of respiratory bronchioles, alveolar duct	Non ciliated cuboidal epithelium
Alveoli	Non ciliated squamous
Alveoli of frog's lungs	Columnar ciliated epithelium

Three special types cell are found in Bronchioles epithelium :

(a) **Kultchitsky cells or argentaffin cells :** They secrete serotonin and histamine. Histamine dilate while serotonin constrict the bronchioles.

(b) **Clara cells :** They secrete a phospholipid named diapalmityl lecithin which acts as a surfactant. This surfactant prevents the collapse of bronchioles lacking cartilagenous rings. Collapsing of lungs is called atelectesis. Pottle in 1956 proved the existence of surfactant. Surfactant is formed by clara cells only at later stage of foetal life. Some times at birth some infants are devoid of surfactant so there is great respiratory difficulty because lungs refuse to expand. In this condition death may occur. This is called respiratory distress syndrome (RDS) or hyaline membrane disease (HMD) or glassy lung disease.

(c) **Dust cells :** They are phagocytes which eat foreign particles (dust).

Respiratory organs

In men the respiratory organ are a pair of lung. Some snakes have unpaired lungs. Respiration by lungs is called pulmonary respiration. Lungs are found in all vertebrates except fishes. In fishes such as protopterus, neoceratodus and lepidosiren air bladder is found, which is modified lung. Respiration in men and rabbit is pulmonary.

Lungs : Lungs lie in thoracic cavity on both side of heart in mediasternum space. Base of lung is attached to diaphragm. Right lung is divided into 3 lobes viz. Superior, Middle, Inferior and left lung is divided into two lobes Superior and Inferior. In rabbit, the left lung is divided into two lobes left anterior and left posterior where as the right lung has four lobes anterior azygous, right anterior, right posterior and posterior azygous. Lungs of reptiles are more complex than those of amphibians. In birds lungs are supplemented by elastic air sacs which increase respiratory efficiency. The narrow superior portion of lung is termed the apex or cupula.

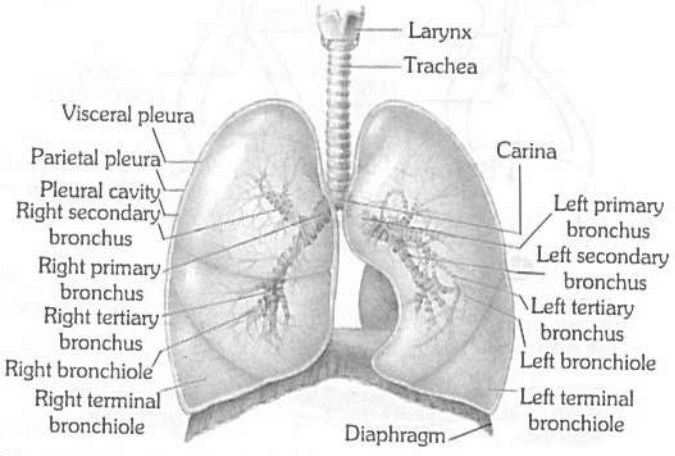


Fig : 5.2-7 Branching of airway from the trachea : the bronchial tree (Anterior view)

Each lung is enclosed in two membrane called pleura. Pleura are layers of peritoneum of thorax. Inner membrane is called the visceral pleuron. It is firmly bound to surface of lungs. The outer membrane is called parietal pleuron. It is attached to chest wall or wall of thoracic cavity. A narrow space exists between the two pleura. It is called pleural cavity. In pleural cavity a watery fluid is found called pleural fluid. Pleural fluid is glycoprotein in nature and secreted by pleura. Pleural fluid lubricate the pleura so that they may slide over each other without friction. This fluids reduces friction between the membrane. When the lungs expand and contract in respiration. Pressure inside pleural cavity is negative – 5 mm Hg. Pleurisy is inflamation of pleura and cause collection of fluid in pleural cavity. It results painful breathing (dyspnea). The surface of lung lying against the ribs, known as coastal surface. The mediastinal (medial) surface of each lung contains a region – the hilus, through which bronchi, pulmonary blood vessels, lymphatic vessels and nerve enter and exit.

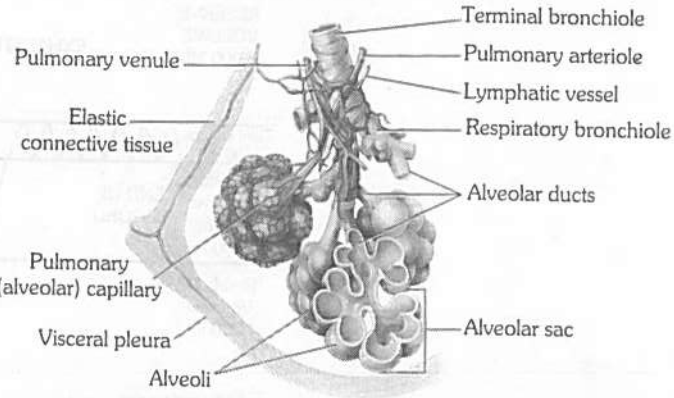


Fig : 5.2-8 Diagram of a portion of a lobule of the lung

Pulmonary volumes and capacities

The apparatus commonly used to measure the volume of air exchanged during breathing and the rate of ventilation is a spirometer (*spiro*=breathe) or respirometer. The record is called a spirogram. There are 4 respiratory volumes and capacity.

Respiratory volumes

(1) **Tidal volume (TV) :** Volume of air inspired or expired in relaxed or resting position – 500 *ml*. It consists of 150 *ml* of dead space volume and 350 *ml* of alveolar volume.

(2) **Inspiratory reserve volume (IRV) :** By taking a very deep breath, you can inspire a good deal more than 500 ml. This additional inhaled air, called IRV is about 3000 ml.

(3) **Expiratory reserve volume (ERV) :** If you inhale normally & then exhale as forcibly as possible, you should be able to push out 1100 ml. of air in addition to 500 ml. of T.V. The extra 1100 ml. is called ERV.

(4) **Residual volume (RV) :** Even after expiratory reserve volume is expelled, considerable air remains in the lung, this volume, which can not be measured by spirometry, it is called residual volume is about 1200 ml.

(5) **Dead space** : Portion of tracheobronchial tree where gaseous exchange does not occur called dead space. It is also called conductive zone. Dead space is 150 ml.

(6) **Functional residual capacity (FRC) :** It is the amount of air that remains in the lungs after a normal expiration. It is about 2300 ml.

$$FRC = ERV + RV$$
$$= 1100 + 1200 = 2300 \text{ ml.}$$

(7) **Vital capacity (VC) :** This is the maximum amount of air that can be expired forcefully from his lungs after first filling these with a maximum deep inspiration. It is about 4600 ml.

$$VC = IRV + TV + ERV$$
$$= 3000+500+1100 = 4600 \text{ ml.}$$

(8) **Total lung capacity (TLC) :** TLC is the sum of vital capacity (VC) and residual volume (RV). It is about 5800 ml.

$$TLC = VC + RV$$
$$= 4600 + 1200 = 5800 \text{ ml.}$$

(9) **Inspiratory capacity (IC) :** It is the total amount of air a person can inspire by maximum distension of his lungs.

$$IC = TV + IRV$$
$$= 500 + 3000 = 3500 \text{ ml.}$$

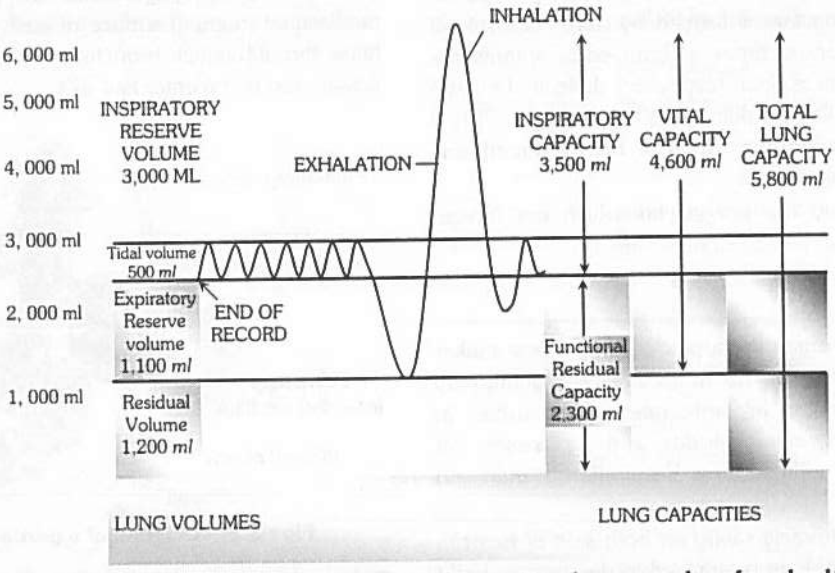


Fig : 5.2-9 Spirogram of lung volumes and capacities (average values for a healthy adult)

Process of Respiration

The process of respiration is completed in 4 steps –

(1) Breathing or ventilation

(2) Exchange of gases or External respiration

(3) Transport of gases

(4) Cellular respiration

(1) **Breathing or ventilation :** Movement of thorax, expansion (inflation) and deflation of lungs and flow of air into the lungs and from the lungs. It is extracellular, energy consuming and physical process. Sum of inspiration and expiration is called respiratory movement. There are two steps of breathing –

(i) **Inspiration :** Intake of fresh air in lungs from outside. It is an active process. Blood pressure increases during later part of respiration. Following muscles are involved in inspiration.

(a) **Diaphragm :** Principle muscles of inspiration. It is a skeletal muscles attached to the sternum, vertebral column and ribs. It is formed by radial muscles fibres.

In relaxed condition it is dome shaped, convex towards thoracic cavity and concave towards abdominal cavity. During inspiration it contracts and become straight and descends down. This causes an increase in vertical diameter of thoracic cavity. Descent of diaphragm can explain about 75% of tidal air volume. 70% muscles fibres of diaphragm have some resistance to fatigue. Nerve which supply to diaphragm is phrenic nerve. Contribution of diaphragm in breathing of full term pregnant lady is 0%. Most important function of diaphragm in mammals is to aid in inspiration. If diaphragm is punctured, respiration will stop and patient will die.

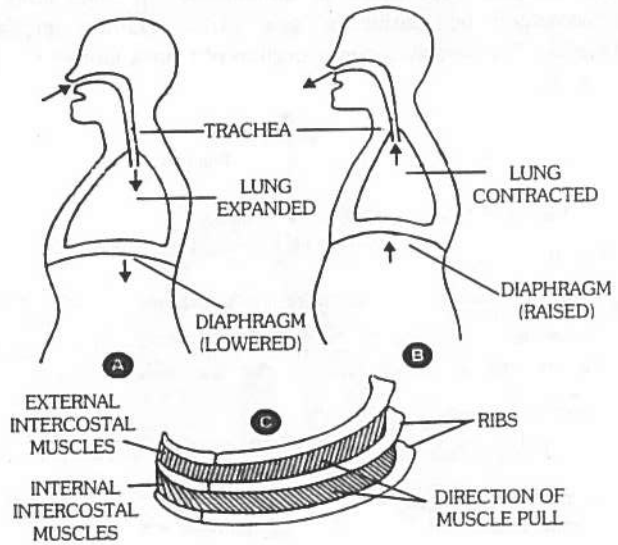


Fig : 5.2-10 Mechanism of breathing. A – Inspiration (Chest cavity enlarged) B – Expiration (Chest cavity reduced) C – Intercostal muscles

(b) **External intercostal muscles :** Gaps between the ribs are called intercostal spaces. They are filled by intercostal muscles. Intercostal muscles are of two types external intercostal muscles and internal intercostal muscles.

External intercostal muscles are related to inspiration and internal intercostal muscles are related to expiration. Here we are concerned with external intercostal muscles. External intercostal muscles start from lower border of upper rib and comes to end outer lip of upper border of lower rib. Thus direction of external intercostal muscles fibres is downward forward. Contraction of external intercostal muscles causes increase in anteroposterior diameter of thoracic cavity and transverse diameter of thoracic cavity.

This two dimensional increase in diameter (i.e. anteroposterior and transverse) of thoracic cavity is due to special arrangement of ribs. This increase in thoracic cavity is assisted by diaphragm the most important muscle of inspiration. Contraction of diaphragm causes it to flatten lowering its dome. For simplification we can assume that each rib is attached anteriorly to sternum by its anterior end and posteriorly to vertebral column by its posterior end. Note these two points carefully –

- Anterior end of rib is lower than the posterior end.
- Middle portion of rib which is called shaft lies at lower level than the two end of rib (i.e. anterior and posterior)

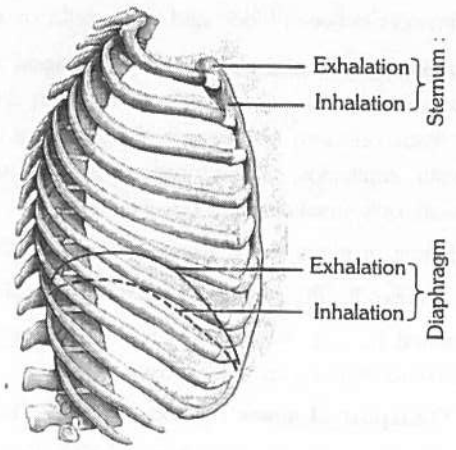


Fig : 5.2-11 Changes in size of thoracic cavity during inhalation and exhalation

(c) **Accessory muscles of inspiration :** These muscles normally are not called into action but in forced inspiration they come into action. Accessory muscles are scaleni, sternomastoid and alae nasi.

(ii) **Expiration :** Out flow of the air from the lungs is called expiration. When the inspiratory muscles relax, the external intercostal relax, ribs move inferiorly and as the diaphragm relaxes, its dome moves superiorly owing to its elasticity. These movements decrese vertical and anterior-posterior dimentions of thoracic cavity.

(a) **Internal intercostal muscles :** Direction of fibres is backward and downward. Action is just opposite to external intercostal muscles. These muscles by their action reduces antero-posterior and transverse diameter of thoracic cavity.

(b) **Abdominal muscles :** Muscles of anterior abdominal wall. These muscles push the diaphragm up.

(iii) **Mechanism of ventilation/breathing**

Inspiration

Enlargement of thoracic cavity due to action of muscles of inspiration.
↓
Lungs follow the enlargement of thoracic cavity and expand.
↓
Expansion of lungs leads to reduction of air pressure within the lungs than the atmospheric pressure.
↓
Air from the outside, where pressure of air is high, comes inside the lungs.
↓
At the top point of inspiration contraction of inspiratory muscles suddenly stops. ← Impulses from CNS
↓

Expiration

Inspiratory muscles relax and also due to the elastic recoil, lungs shrink.
↓
Air pressure within lungs exceeds atmospheric air pressure.
↓
Air is expelled out into the atmosphere.

(2) **Exchange of gases**

(i) **Exchange of gases in lungs :** It is also called external respiration. In this gaseous exchange oxygen passes from alveoli to pulmonary capillary blood and CO_2, comes to alveoli from pulmonary capillary. In order to exchange the gases have to pass through alveolocapillary membrane or respiratory membrane. Composition of alveolocapillary membrane is epithelium lining of alveolar wall, epithelial basement membrane, a thin interstitial space, capillary basement membrane and capillary endothelial membrane.

Thickness of respiratory membrane is 0.5 μm. Respiratory membrane has a limit of gaseous exchange between alveoli and pulmonary blood. It is called diffusion capacity. Diffusion capacity is defined as volume of gas that diffuse through membrane per minute for a pressure difference of 1 *mm Hg*. Exchange of gases through alveolocapillary membrane is a purely physical diffusion phenomenon. No chemical reaction is involved. Diffusion of a gas depends upon pressure gradient across the membrane and solubility of gas.

Partial pressure : Partial pressure of a gas is the pressure it exerts in a mixture of gases, and is equal to the total pressure of the mixture divided by percentage of that gas in the mixture. For instance, if the pressure of atmospheric air at sea level is 760 *mm.* of mercury (*Hg*) and oxygen forms 21% of the air, the partial pressure of oxygen will be 21% of 760, or 159 *mm. Hg*. In other words, the partial pressure of a gas is proportional to its concentration in the mixture. Only about 0.3 *ml.* of O_2 can dissolve in 100 *ml.* of plasma, about 20 *ml.* of O_2 is carried by haemoglobin in 100 *ml.* of blood. In atmospheric air except these gases some traces of helium, argon and neon are also found.

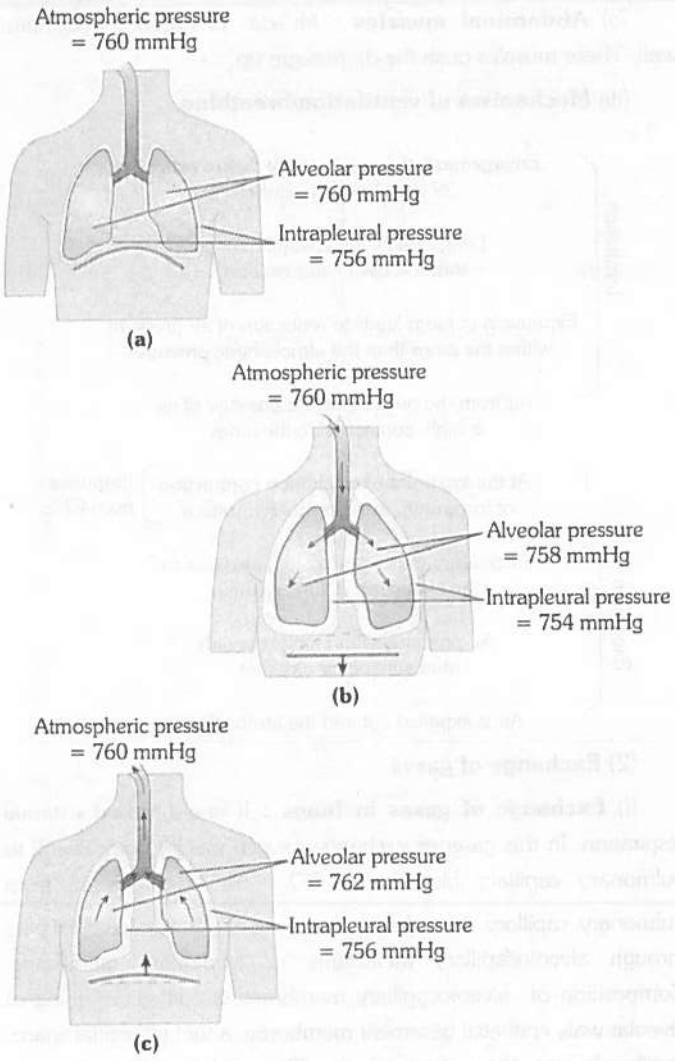


Fig : 5.2-12 Pressure changes in pulmonary ventilation ; (a) At rest (diaphragm relaxed) (b) During inhalation (diaphragm contracting) (c) During exhalation (diaphragm relaxing)

Table : 5.2-4 Partial pressures of respiratory gases in *mm. Hg*

Gas	Oxygen	Carbon dioxide	Nitrogen
Inspired air	158	0.3	596
Alveolar air	100-105	40	573
Venous blood	40	46	573
Arterial blood	95-100	40	573
Expired air	116	32	565
Tissue cells	20-40	45-52	–

Table : 5.2-5 Composition of three samples of air

Gas	Oxygen	Carbon dioxide	Nitrogen	Water
Inspired air	20.84%	0.04%	78.62%	0.5%
Expired air	15.70%	4.00%	74.50%	6.2%
Alveolar air	13.6%	5.3%	74.9%	6.2%
Gain/loss %	Gain 5.14%	Loss 3.96%	Gain 4.12%	Loss 5.7%

Exchange of gases in lungs can be divided into two steps –

Uptake of O_2 by blood in lung : The PO_2 (partial pressure of oxygen) of the alveolar air is higher than the PO_2 of blood in alveolar capillaries. Due to a PO_2 difference between air and blood, oxygen diffuses rapidly from the alveolar air into the blood of alveolar capillaries.

Release of CO_2 by the blood : The PCO_2 (partial pressure of carbon dioxide) of blood reaching the alveolar capillaries is higher than the PCO_2 of alveolar air. Therefore, carbon dioxide diffuses from the blood of alveolar capillaries into the alveolar air.

(ii) **Exchange of gases in tissues :** In the tissues, exchange of gases occurs between the blood and the tissue cells. This exchange occurs *via* tissue fluid that bathes the tissue cells. The blood reaching the tissue capillaries has PO_2 higher than that in the tissue cells and PCO_2 lower than that in the tissue cells. The tissue cells constantly use oxygen in oxidation that produces carbon dioxide. Therefore, they always have lower PO_2 and higher PCO_2 than the blood coming to them. Because of PO_2 and P_{CO_2} differences between blood and tissue cells, oxygen separates from oxyhaemoglobin and diffuses from the blood into the tissue fluid and hence into the tissue cells; and carbon dioxide diffuses from the tissue cells into the tissue fluid and thence into the blood in the tissue capillaries. Gases mostly diffuse through the tissue fluid as such, only small amounts dissolve in it.

Exchange of gases in the tissues that lowers the PO_2 of the blood and raises its PCO_2 is called internal respiration. The blood deoxygenated by this respiration returns to the right side of the heart that sends it to the lungs for reoxygenation.

(3) **Transport of gases :** Blood carries O_2 from respiratory organs to the tissue cells for oxidation and CO_2 from tissue cells to respiratory organs for elimination. Blood should be slightly alkaline to help the transport of O_2 and CO_2 properly.

(i) **Transport of oxygen :** Lung contains atmospheric air. From the lung O_2 diffuses into the blood. The blood transport O_2 from the lung to the cells. This is called oxygen transport. O_2 is carried in the blood in three forms –

(a) **In physical solution :** 100 *ml.* oxygenated blood contains 20 *ml* (0.3 *ml* dissolved in plasma and 19.7 *ml* bound to *Hb*) of oxygen. 2-3% oxygen is transported in form of physical solution. Thus 0.3 *ml* to 0.6 *ml.* O_2 is in physical solution form in 100 *ml* of blood.

(b) **As oxyhaemoglobin (HbO_2) :** Most of O_2 is transported in the form of oxyhaemoglobin. 98.5% in the form of HbO_2 and 1.5% is carried in the dissolved state in watery blood plasma.

Oxygen-haemoglobin dissociation curve

When a graph is plotted between percent saturation of haemoglobin and oxygen tension, a curve is obtained termed as O_2 - *Hb* dissociation curve. Oxygen-*Hb* dissociation curve is sigmoid shaped-or *S* shaped. This *sigmoid shaped* curve is characteristic for *Hb*.

Body tissue obtain oxygen from oxyhaemoglobin because of its dissociation caused by low O_2 and high CO_2 concentration. Under a given oxygen concentration in blood, dissociation of oxyhaemoglobin will increase if pH of blood falls. When partial pressure of CO_2 rises (blood pH decreases), dissociation curve of oxyhaemoglobin at 37°C shift to right. Effect of high temperature and low pH (high PCO_2) are similar. P_{50} indicates the oxygen concentration at which 50% haemoglobin of blood is saturated with O_2.

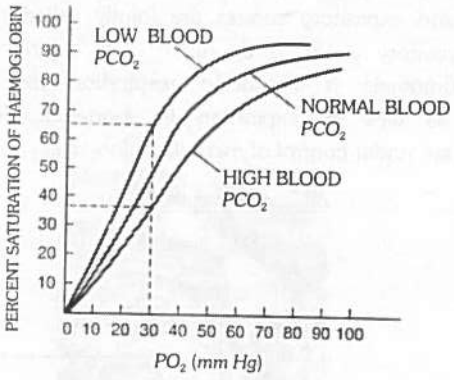


Fig : 5.2-13 Effect of PCO_2 on affinity of hemoglobin for oxygen

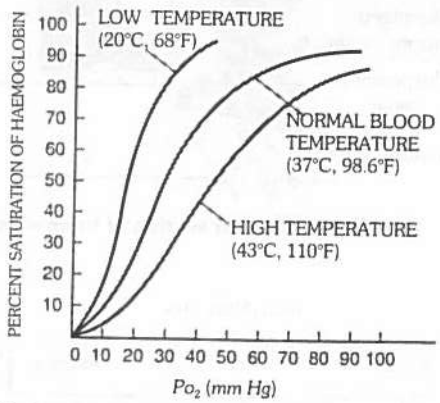


Fig : 5.2-14 Oxygen-hemoglobin dissociation curve showing the relationship between temperature and hemoglobin saturation with O_2

Bohr's effect : *Hb*-O_2 dissociation curve shifts to right when CO_2 tension in blood is high. Bohr discovered this effect in 1904. Bohr effect is the effect of CO_2 on oxyhaemoglobin. Deoxygenation of oxygaemoglobin is directly proportional to blood pCO_2. Extent of Bohr's effect depends upon the tension of CO_2 in blood only. CO_2 of tissue fluid and alveoli does not exert Bohr's effect. During exercise muscles need more O_2 and want to remove CO_2 which has high production. Because of pressure gradient CO_2 moves from tissues fluid to capillary blood → Exert Bohr's effect → O_2 release is hastened from *Hb*-O_2 *i.e.* *Hb*-O_2 curve shifts to right.

Haemoglobin : Oxygen carrier or respiratory pigment in vertebrates blood is haemoglobin. *Hb* molecule is made of two components haem and globin. Globin part is globulin protein which is made of four polypeptide chain, two α chains (141 amino acid) and two β chains (146 amino acid). Thus total no. of amino acid in *Hb* 574. Haem is iron containing compound and belongs to the class of compound called protoporphyrins. *Hb* in RBC synthesized before loss of nucleus. Iron of *Hb* is in ferrous state (Fe^{++}) and even after the combination with O_2 it remains ferrous. One *Hb* molecule has 4 haem molecules. Each haem is associated without polypeptide chain. Each *Hb* molecule can combine with one molecule (2 atoms) of oxygen. Thus each molecule of *Hb* combines *4* molecules of O_2.

Myoglobin : It is chemically and functionally similar to *Hb*. It is made up of one polypeptide chain (153 amino acids) attached with on haem group. P_{50} value for myoglobin is 5 *mm Hg*. This indicates that myoglobin release oxygen less readily than *Hb*. It is found in muscles. It acts as a store house for O_2. An average man can store about 1.5 *litre* oxygen in myoglobin. *Hb*-O_2 dissociation curve for myoglobin is hyperbola.

(ii) **Transport of CO_2 :** Transportation of CO_2 by blood is much easier due to its high (20 times that of O_2) solubility in water. Blood can carry upto 50% or 60% of CO_2 by volume, but normally about 4 ml of CO_2 on an average is transported from tissue to the lungs in each 100 ml of blood in man. With 5 litres of cardiac output per minute, the blood thus transports about 200 to 220 ml of CO_2 each minute. Obviously, this is the rate at which CO_2 is produced and released into tissue fluids by cells, and at which it diffuses out into alveolar air from pulmonary arterial blood. The blood transports this CO_2 in three ways.

(a) **In dissolved state :** Deoxygenated (PCO_2 is 45 to 46 mm Hg) and oxygenated (PCO_2 is 40 mm Hg) bloods respectively carry about 2.7 and 2.4 ml of CO_2 per 100 ml of blood in dissolved state in plasma (= in solution with plasma). Thus, about 0.3 (2.7 minus 2.4) ml of CO_2 is transported by each 100 ml. of blood in dissolved state in plasma. This is about 7% of all the CO_2 transported by blood from tissues to the lungs.

(b) **In the form of bicarbonate ions :** Most of the CO_2 that dissolved in blood plasma reacts with water, forming carbonic acid – $CO_2 + H_2O \rightleftharpoons H_2CO_3$ (carbonic acid)

This reaction is very slow in plasma, but occurs very rapidly inside RBCs, because an enzyme, carbonic anhydrase, present in RBCs, accelerates its rate about 5000 times. That is why, about 70% of the CO_2 (about 2.5 ml per 100 ml of blood), received by blood from the tissues, immediately enters into RBCs and hydrated to carbonic acid. Almost as rapidly as formed, all carbonic acid of RBCs dissociates into hydrogen and bicarbonate ions (H^+ and HCO^-_3). The hydrogen ions mostly combine with heamoglobin for

keeping the pH of blood. (7.4) in steady state, because haemoglobin is a powerful acid base buffer. Being quite diffusible, the bicarbonate ions, on the other hand, diffuse from RBCs into the plasma. To maintain electrostatic neutrality of plasma, many chloride ions, in turn, diffuse from plasma into the RBCs. Obviously, the chloride contents of RBCs increase when oxygenated blood becomes deoxygenated. This is termed "chloride or Hamburger shift".

Sequence of events : From tissues CO_2 enters in plasma → a small fraction of CO_2 is dissolved in plasma → rest of CO_2 enters into the RBC → within RBC CO_2 combines with H_2O in presence of enzyme carbonic anhydrase and forms $H_2CO_3 \rightarrow H_2CO_3$ splits into H^+ and $HCO_3^- \rightarrow$ most of the HCO_3^- comes out of RBC and enters in plasma and form $NaHCO_3$, small fraction stays back within the RBC to form $KHCO_3$ and H^+ combine with Hb to form reduced haemoglobin $H.Hb$.

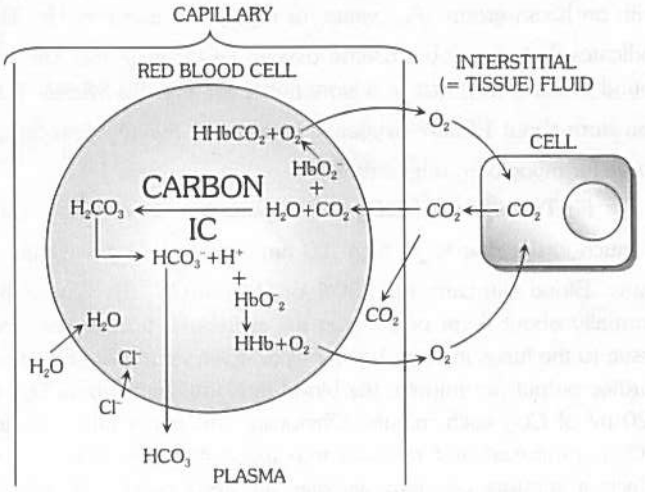


Fig : 5.2-15 Transportation of CO_2 by blood

(c) **In the form of carbamino compounds :** In addition to reacting with water, CO_2 also directly and reversibly reacts with haemoglobin, loosely binding with it and forming an unstable compound, called carbaminohaemoglobin (CO_2HHb). It also similarly forms loose bonds with some plasma proteins. It is estimated that about 23% of the CO_2 (1 ml per 100 ml of blood), collected from cells through tissue fluids, is transported by blood in this form.

Table : 5.2-6 Transformation of CO_2 in various forms

Transformation forms of CO_2	Transported quantity
CO_2	7 % (0.3 ml/100ml of blood)
$HHbCO_2$	23% (1ml/100 ml of blood)
HCO_3^-	70% (2.5 ml/100 ml of blood)

Haldane effect and CO_2 diffusion into the alveoli : Whereas the Bohr effect promotes O_2 transport, the Haldane effect is important in promoting CO_2 transport. The Haldane effect results from the simple fact that oxyhaemoglobin behaves as a strong acid. This in turn, displaces CO_2 from the blood in two ways.

(1) Due to its increased acidity, the haemoglobin loses its capacity to combine with CO_2. Hence all carbamino haemoglobin dissociates to release its CO_2.

(2) Secondly, the highly acidic oxyhaemoglobin releases an excess of H^+ which bind with bicarbonate ions (HCO_3^-), forming carbonic acid. The latter soon dissociates into H_2O and CO_2. This CO_2 diffuses into the alveoli.

Thus, in the lung, the haldane effect, increases release of CO_2 because of O_2 uptake by haemoglobin. In the tissues a reverse process occurs. The Haldane effect increases CO_2 uptake because of removal of O_2 from haemoglobin.

Control of breathing

Respiratory rhythm is controlled by nervous system. Inspiratory and expiratory centres are jointly called rhythmicity centres. Inspiratory centre is dominant over expiratory centre. When pneumotaxic is stimulated respiration rate increases inspiration as well as expiration is shortened. Respiratory movements are under control of *medulla oblongata*.

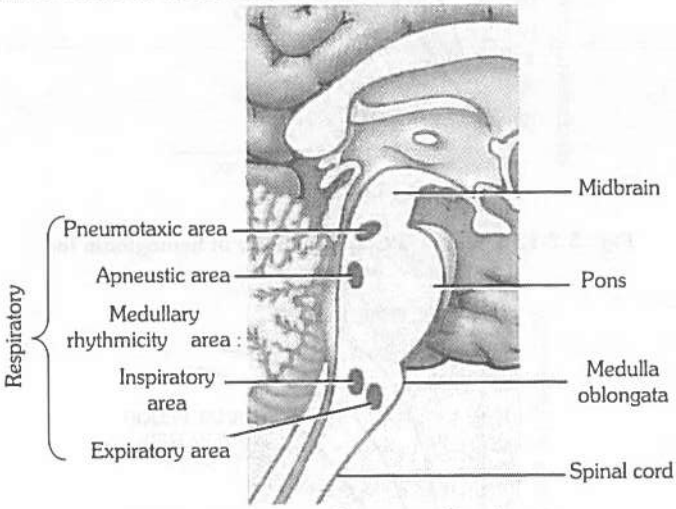
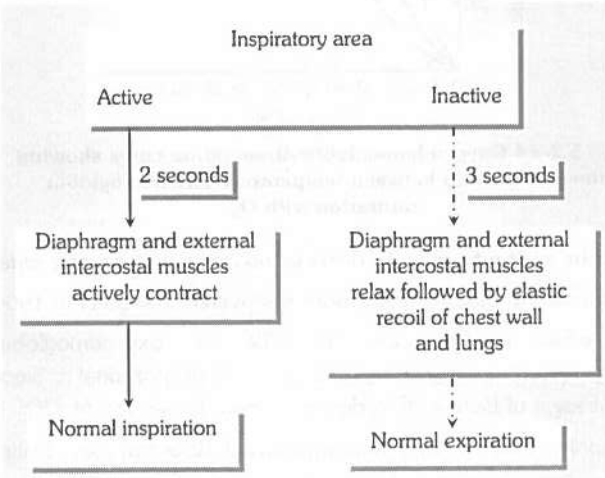
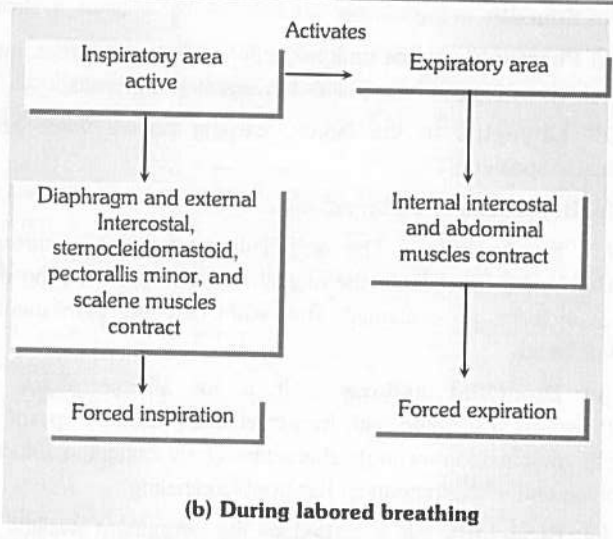


Fig : 5.2-16 Sagittal section of brain stem



(a) During normal quiet breathing



(b) During labored breathing

Table : 5.2-7 For the control of respiration following respiratory centres are found in hind brain

Type of centre	Location	Function
Inspiratory centre	Medulla oblongata	Inspiration (2 second active condition).
Expiratory centre	Medulla oblongata	Expiration (3 second inactive condition)
Apneustic centre	Pons	Slow and deep inspiration
Pneumotaxic centre	Pons	Control other centres and produce normal quite breathing
Gasping centre	Pons	Sudden and shallow respiration

(1) **Chemical control :** This includes CO_2, O_2 and H^+ conc. of blood. For detection of concentration of O_2, CO_2 and H^+ ions in blood two types of receptors are found. These receptors are called chemoreceptor.

(i) **Peripheral chemoreceptor :** These include two sets – Carotid body is present in the wall of the left and the right common carotid arteries and aortic bodies is present in the arch of aorta. They are placed in the vascular endothelium and come in contact with the blood. When PO_2 decreases or increases in arterial blood, these receptors are stimulated and send impulses to respiratory centre to respectively increases or decreases the rate intensity of inspiratory signals.

(ii) **Central chemoreceptors :** These are present on ventral surface of medulla. Cells of these centres are bathed in brain tissue fluid. They are in close vicinity of CSF. In brain tissue fluid as well as in CSF the CO_2 is converted into $H_2CO_3 \rightarrow H_2CO_3$ $H^+ + HCO_3^- \rightarrow H^+$ ions are liberated $\rightarrow$ H^+ ions stimulate the central chemoreceptor (C.C) cell $\rightarrow$ stimulation from C.C goes to respiratory centre $\rightarrow$ Respiration stimulate.

(2) **Effect of different gases**

(i) **Effect of CO_2 :** Rise in tension of arterial CO_2 or alveolar CO_2 causes stimulation of respiration. Both the rate and depth of respiration increased. This leads to washing out of CO_2 from body.

(ii) **Effect of O_2 :** Fall of O_2 concentration in inspired air causes stimulation of peripheral chemoreceptors. Neural impulse arises from peripheral chemoreceptors. These impulses go to respiratory centre and cause respiratory stimulation.

Respiration in frog

Frog is an amphibious animal *i.e.* they are live in water as well as on land hence according to their adaptations they posses different modes of respiration, which are as follows –

(1) **Cutaneous respiration :** By the skin. Under water, during hibernation frog respires by only skin. On land cutaneous respiration continues as usual. Thus cutaneous respiration take place always. By cutaneous respiration frog fulfill its 30% need of oxygen.

(2) **Buccopharyngeal respiration :** Like the skin, the mucosa of buccopharyngeal cavity in frog is also ideally adapted for gaseous exchange. Hence, while quietly floating upon water surface, and even when resting upon land, frogs respire by their buccopharyngeal cavity also. During this process, the mouth, gullet and glottis remain closed, but nares remain open.

(3) **Pulmonary respiration :** In frog, pulmonary respiration accounts for about 65% of the total O_2-intake. It particularly occurs when frogs lead an active life during rains and spring; either hopping upon land in search of food, or actively breeding in water.

Important concept of respiration

(1) **Respiratory quotient (R.Q.) :** Respiratory quotient is the ratio of carbon dioxide output to oxygen usage during respiration. It is measured by Ganong's respirometer.

$$\text{R.Q.} = \frac{\text{Volume of } CO_2 \text{ formed}}{\text{Volume of } O_2 \text{ utilized}}$$

Table : 5.2-8

High RQ	Low RQ
Due to fat deposition	When CO_2 is fixed
Due to fever	When CO_2 retain in tissue
Due to muscle exercise	In hibernating mammals
During glycolysis	Due to acidosis
In low O_2 environment	Due to alkalosis
Due to oxidation of pyruvic acid.	Due to diabetes
	In starvation
	During gluconeogenesis
	During glyconeogenesis

The volume of RQ depends upon the type of fuel substance being utilized for energy production.

Table : 5.2-9 RQ of various subtrates

Respiratory substrate	Respiratory quotient
Carbohydrate	1.00
Proteins	0.5 – 0.9 Slightly less than 1 (0.9)
Fats	0.7
Organic acid	1.33

In an organism utilizing carbohydrates as source of energy anaerobically, the RQ is likely to be infinity. When carbohydrates are substrates for respiration, it is called 'floating respiration'. Diabetic patient shows low R.Q. due to increased dissimilation of fats and the decreased dissimilation of carbohydrate.

(2) **Effect of *CO* :** Carbon monoxide is a poisonous gas. *Hb* has maximum affinity for *CO*. Carbon monoxide binds with haemoglobin at the same place where O_2 binds, but about 250 times more readily than O_2. Hence, it readily displaces O_2 from haemoglobin and even a *0.4 mm Hg* partial pressure of *CO* in alveolar air is enough to occupy about half of the haemoglobin of pulmonary blood rendering it useless for O_2 transport. A *CO* pressure of about 0.7 *mm Hg* (concentration of about 1%) in alveolar air can be lethal. That is why, the atmosphere of industrial areas, being loaded with chimney smoke, is regarded harmful to health. It forms carboxyhaemoglobin with *Hb* which is most stable. Sudden deep inspiration is due to either increase in concentration of CO_2 or decrease in concentration of O_2. Forced deep breathing for a few minutes by a person sitting at rest may be followed by a temporary cessation of breathing. This is influenced by too much O_2 and least CO_2 in blood.

(3) **Regulation at high altitudes :** At high altitudes, the composition of air remains almost the same as at sea-level, but the density (barometric pressure) of air gradually decreases. While ascending up a mountain, one inspires thin air, getting less oxygen. Less O_2 level in the blood results in hypoxia. The chemoreceptor simulatory mechanism progressively increases the rate of ventilation. Ventilation ordinarily does not increase significantly until one has ascended to about 2500 *metres*, because the P_{CO_2} and *pH* remain almost normal.

Disorders of Respiratory system

(i) **Hypoxia :** Hypoxia is a condition of oxygen shortage in the tissues. It is of two types :

(a) **Artificial Hypoxia :** It results from shortage of oxygen in the air as at high (over 2400 *m*.) altitudes. It causes mountain sickness characterised by breathlessness, headache, dizziness, nausea, vomiting, mental fatigue and bluish tinge on the skin and mucous membranes.

(b) **Anaemic Hypoxia :** It results from the reduced oxygen-carrying capacity of the blood due to anaemia (decreased haemoglobin content in blood) or carbon monoxide poisoning (some haemoglobin occupied by *CO*). in both cases, less haemoglobin is available for carrying O_2.

(ii) **Asphyxia (Suffocation) :** The O_2 content of blood falls and the CO_2 content rises and paralyses the respiratory centre. Breathing stops and death occurs.

(iii) **Bad cold :** Disease-causing microbes present in the air attack respiratory tract, producing inflammation of the mucous membrane and caused increased secretion :

(a) **Rhinitis** in the nasal chambers.

(b) **Sinusitis** in the sinuses.

(c) **Pharyngitis** in the pharynx, often called sore throat, and is usually accompanied by tonsillitis (enlargement of tonsils).

(d) **Laryngitis** in the larynx, causing hoarse voice and difficulty in speaking.

(e) **Bronchitis** in the bronchioles.

(iv) **Emphysema :** The air-pollutants that cause chronic bronchitis, may breakdown the alveoli of the lungs, reducing the surface area for gas exchange. The victim becomes permanently short of breath.

(v) **Bronchial asthma :** It is an allergic attack of breathlessness associated with bronchial obstruction or spasm of smooth muscle (contraction), characterized by coughing difficult breathing and wheezing patient has trouble exhaling.

(vi) **Bronchitis :** It is caused by the permanent swelling in bronchi. As a result of bronchitis cough is caused and thick mucus with pus cells is spitted out. Dyspnea and fever develops. Dyspnea means hunger of air or deficiency of oxygen in the blood or development of hypercapnia *i.e.*, increase of CO_2 concentration in blood. This disease is accelerated by fatigue, malnutrition, cold etc. the patient experiences difficulty in breathing. Here hypertrophy and hyperplasia of bronchi takes place.

(vii) **Pneumonia :** Oxygen has difficulty diffusing through the inflammed alveoli and the blood PO_2 may be drastically reduced. Blood PCO_2 usually remain normal because CO_2 diffuses through the alveoli more easily than O_2. In chronic patients of common cold and influenza, the lining epithelium of bronchi and lungs is inflammated. This disease is caused by streptococus pneumoniae, other bacteria, fungi, protozoans, viruses and the patient feels difficulty in breathing. Its prominent symptoms are trembling, pain in chest, fever, cough delirium etc. This disease is prevalent in either children or elderly persons in old age.

(viii) **Lung cancer :** It is believed that by excess smoking, lung cancer (carcinoma of lungs) is caused. The tissue increases limitlessly, which is called malignancy. This disease is fatal. The frequency of occurrence of this disease in smokers is 20% more. Malignancy of tissues (neoplasia) causes pressure on the cells of other tissues and destroys them. The blood capillaries are ruptured, blood starts flowing and death is caused by excessive bleeding.

(ix) **Tuberculosis :** This disease is also called T.B. and was considered fatal, but these days its full cure is possible. Thus, disease is called curable, these days. It is caused by bacteria Mycobacterium tuberculosis. These bacteria settle in lungs at different places and convert normal tissue into fibrous tissue. Since the respiratory surface is decreased, the difficulty in breathing is also experienced. If the patients start taking medical advice and the medicines right from the initial stage regularly, the patients can be fully cured of the disease. Now a days a new therapy DOT (Direct observed treatment) is used for tuberculosis treatment, recently launched by Indian Government. Many other drugs like rifampin and isoniazid are successful for the treatment of tuberculosis. Tuberculosis bacteria are spread by inhalation and exhalation.

(x) **Coryza :** Common cold, due to rhinoviruses in adult.

(xi) **Influenza :** Flu.

(5) **Occupational lung disease :** It is caused because of the exposure of potentially harmful substances. Such as gas, fumes or dusts, present in the environment where a person works. Silicosis and asbestosis are the common examples, which occur due to chronic exposure of silica and asbestos dust in the mining industry. It is characterised by fibrosis (proliferation of fibrous connective tissue) of upper part of lung, causing inflammation.

(i) **Prevention and cure :** Almost all the occupational lung diseases, express symptoms after chronic exposure, *i.e.*, 10-15 years or even more. Not only this, diseases like silicosis and asbestosis are incurable. Hence, the person likely to be exposed to such irritants should adopt all possible preventive measures. These measures include :

(a) Minimizing the exposure of harmful dust at the work place.

(b) Workers should be well informed about the harm of the exposure to such dusts.

(c) Use of protective gears and clothing by the workers at the work place.

(d) Regular health check up.

(e) Holiday from duty at short intervals for the workers in such areas.

(f) The patient may be provided with symptomatic treatment, like bronchodilators and antibiotics, to remove underlying secondary infection.

(6) **Special respiratory movements**

Cough

(1) It is reflex action stimulation takes place from trachea and lungs.

(2) Centre is medulla oblongata.

(3) Cough is a forcible expiration usually produced after a prolonged inspiration.

(4) When some food particle enters the windpipe instead of oesophagus, it is expelled by a process of coughing.

(5) Air exploded through the mouth.

Sneezing

(1) Reflex action stimulated by olfactory epithelium of nasal chamber.

(2) Sneezing is a forcible expiration, air explodes out through nose and mouth.

Hiccuping

(1) Hiccuping is a noisy inspiration caused by muscular spasm of diaphragm at irregular intervals.

(2) Noise is due to sudden sucking of air through vocal cords.

(3) Stimulation of hiccuping is usually irritation of the sensory nerve endings of the digestive tract.

Yawning : Yawning is a prolonged inspiration. Low oxygen tension in the blood causes yawning.

Table : 5.2-10 Terminology

Apnea	Absence of breathing
Eupnea	Normal breathing
Hypopnea	Decreased breathing rate
Hyperpnea	Increased breathing rate
Dyspnea	Painful breathing
Orthopnea	Inability to breathe in a horizontal position
Acapnoea	Absence of CO_2 in blood
Hypocapnea	Deficiency of CO_2 in blood
Hypercapnea	Excess of CO_2 in blood
Hypoxaemia	Lack of O_2 in arterial blood
Anoxia	Absence of O_2 in tissues
Hypoxia	Lack of O_2 in tissues
Tachypnea	Rapid breathing

Table : 5.2-11 Respiratory pigments

Name of pigment	Colour (oxidised)	Metal	Place	Example
Haemoglobin	Red	Fe	RBC	Chordata (Vertebrate)
Haemocyanin	Blue	Cu	Plasma	Mollusca and arthropoda
Chlorocruorin	Green	Fe	Plasma	Annelida, sabella, serpulids
Haemoerythrin	Red	Fe	Corpuscle	Annelida, Sipunculoid ea, lingula
Vanadium	Green	Va	Vanadocytes in Plasma	Urochordat a
Echinochrome	Red	Fe	Coelomic fluid	Echinoderm ata
Pinnoglobin	Brown	Mn	Coelomic fluid	Pinna
Moledin	Brown	Mo	Coelomic fluid	Holothuria
Heamoglobin	Red	Fe	Plasma	Earthworm, nereis, arenicola, chironomas insect, planorbis.
Erythrocruonin	Red	Fe		Leech

Tips & Tricks

- Protoplasmic respiration refers to the respiration of proteins.
- Polarography is employed to measure the concentration of oxygen in fluid.
- Accumulation of blood in pleural cavity is called haemothorax.
- Accumulation of water is called hydrothorax.
- Accumulation of pus is called pyothorax.
- Accumulation of air is called pneumothorax.
- Besides lungs, the term alveolus is associated with bony socket for tooth, and in mammary glands also.
- In general, a man respires about 16 - 18 time in a minute.
- A new born child respires 32/min.
- A five year old child respires 26/min.
- A fifty year old man respires 18/min.
- No respiratory pigment in cockroach.
- Smaller the animal higher the respiratory rate.
- Rate of respiration is directly proportional to concentration of CO_2 in blood.
- Metabolic rate of body is directly proportional to the total pulmonary ventilation.
- Intra aortic balloon pump is inflated by helium.
- In pregnant woman diaphragm does not take part in breathing.
- In frog larynx and trachea are fused together to form laryngo tracheal chamber.
- Lungs of frog acts as positive pressure pump, while lungs of mammal acts as negative pressure pump.
- Disorder such as asthma and emphysema can greatly reduce the expiratory reserve volume.
- At about 4 weeks foetal development, the respiratory system begins as an outgrowth of endoderm of foregut, known as laryngotracheal bud.
- After 6 months, formation of alveoli of lungs.
- The pneumotoxic and the apneustic area in pons.
- If arterial PCO_2 is more than 40 *mm Hg*, the condition is called as hypercapnia.
- If arterial PCO_2 is lower than 40 *mm Hg*, the condition is called as hypocapnia.
- Double Bohr effect refers to the situation in the placenta where the Bohr effect is operative in both the maternal and foetal circulation.
- Ozone, a strong oxidizing agent, oxidises iron of *Hb* and forms a stable compound methaemoglobin which can not release O_2.
- Air bladder perform the functions of hydrostatic organ, sound production, audition and respiration.
- Foetal Hb takes O_2 from mother haemoglobin across the placenta due to double Bohr effect.
- In embryos of mammals, respiration takes place by chorion.
- In lungs of birds capillaries are present in place of alveoli.
- Exchange of O_2 takes place twice in lungs of birds. It is called double respiration.
- Aquatic salamander is lungless amphibians.
- In snakes, only right lung in functional, left lung is reduced.
- In penguins double trachea is present.
- In pregnant females most part during breathing is played by intercostal muscles.
- Whales and other aquatic mammals suffocate on land because their intercostal muscles can not expand their chest due to their massive body weight.
- In monkeys, kangaroo and other jumping animals, intercostal muscles play important role in breathing.
- **Smoke inhalation injury –** Has three components that occur in sequence

  Inhibition of O_2 delivery and utilization.

  Upper airway injury from heat.

  Lung damage from acid and aldehyde in smoke.
- **SARS – Severe Acute Respiratory Syndrome –**

  SARS is a highly infectious disease caused by corona virus.

  Corona virus is a RNA virus, its genome was sequenced within 15 days.

  The origin of SARS is from South China, this disease spread to Hongkong.

  Bird sellers and persons in contact with birds suffer from SARS.

  Symptoms of infections are flue like. Fever occurs with dry cough. There is difficulty in breathing. Fluid fills in lungs and death occurs within one week of infection from respiratory failure.

  Rate of death was initially 4% but now death rate has increased to 10%.

  Line of treatment is quarnatine and ribovinin durgs.

  The causative agent of SARS was identified by Dr. Malik Peiris of Microbiology Department of Hongkong University.

OT Ordinary Thinking

Objective Questions

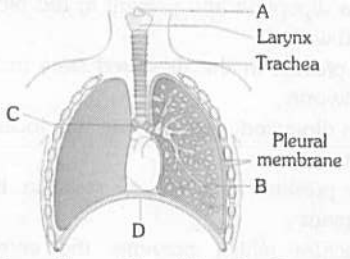
Respiratory organs

1. Which one of the following has the smallest diameter **[NCERT; Kerala CET 2003]**
(a) Right primary bronchus (b) Left primary bronchus
(c) Trachea (d) Respiratory bronchiole

2. Oxygen in lungs ultimately reaches in **[MP PMT 1998]**
(a) Alveoli (b) Trachea
(c) Bronchus (d) Bronchioles

3. Respiratory pigment in cockroach is **[RPMT 1999; Odisha JEE 2010]**
(a) Haemozoin (b) Haemocyanin
(c) Haemoglobin (d) Absent

4. See the following diagrammatic view of human respiratory system. Identify A to D **[NCERT]**



(a) A - Soundbox, B - Alveoli, C - Bronchioles, D - Diaphragm
(b) A - Soundbox, B - Alveoli, C - Bronchus, D - Diaphragm
(c) A - Epiglottis, B - Alveoli, C - Bronchioles, D – Diaphragm
(d) A - Epiglottis, B - Alveoli, C - Bronchus, D - Diaphragm

5. In man and mammals, air passes from outside into the lungs through **[NCERT; BHU 1999; CPMT 2000]**
(a) Nasal cavity, larynx, pharynx, trachea bronchi, alveoli
(b) Nasal cavity, larynx, pharynx, trachea, bronchioles, alveoli
(c) Nasal cavity, pharynx, larynx, trachea, bronchioles, bronchi, alveoli
(d) Nasal cavity, pharynx, larynx, trachea, bronchi, bronchioles, alveoli

6. Which of the following is a respiratory organ of scorpion **[CBSE PMT 2002; BVP 2002]**
(a) Gill (b) Lung
(c) Ctenidia (d) Book lung

7. During forced expiration, actively contracting muscles include the **[CBSE PMT 2001]**
(a) Diaphragm
(b) External intercostals
(c) Abdominal muscles
(d) Diaphragm and intestinal muscle

8. In which part gaseous exchange take place in rabbit **[NCERT; RPMT 2001]**
(a) Trachea and alveolar duct
(b) Trachea and bronchi
(c) Alveolar duct and alveoli
(d) Alveoli and tissues

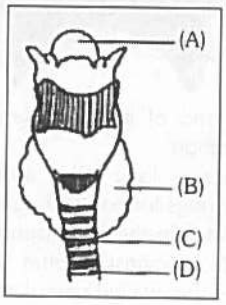
9. Difference between trachea and fallopian tube is **[CPMT 1995]**
(a) Trachea is related with respiration where as fallopian tube is related with reproduction
(b) Trachea is related with respiration and fallopian tube with excretion
(c) Trachea is related with reproduction and fallopian tube with excretion
(d) Trachea is related with reproduction and fallopian tube with respiration

10. Vocal cords are situated at **[MP PMT 1995, 99]**
(a) Pharynx (b) Larynx
(c) Glottis (d) Bronchial tube

11. Carbon dioxide is transported via blood to lungs mostly **[CBSE PMT 1995; Odisha JEE 2008]**
(a) As carbaminohaemoglobin and as carbonic acid
(b) In the form of carbonic acid only
(c) In combination with haemoglobin only
(d) Dissolved in blood plasma

12. Which is a common passage in swallowing food and breathing **[CPMT 1993; MP PMT 1995]**
(a) Larynx (b) Gullet
(c) Glottis (d) Pharynx

13. The diagram represents the human larynx. Choose the correct combination of labelling from the options given **[Kerala PMT 2008]**



(a) A – Larynx, B – Parathyroid, C – Tracheal cartilage, D – Trachea
(b) A – Naso Larynx, B – Thyroid, C – Tracheal cartilage, D – Trachea
(c) A – Trachea, B – Thyroid, C – Bronchiole, D – Tracheal cartilage
(d) A – Epiglottis, B – Thyroid, C – Tracheal cartilage, D – Trachea
(e) A – Epiglottis, B – Parathyroid, C – Trachea, D – Tracheal cartilage

14. In human beings, lungs are divided into
(a) 3 right and 2 left lobes (b) 2 right and 3 left lobes
(c) 2 right and 2 left lobes (d) None of these

15. Similarity between the trachea of cockroach and rabbit is that **[AFMC 1994; CPMT 1995]**
(a) Both are paired and branched
(b) Ciliated epithelium is present in both
(c) Walls of both can not be deformed
(d) In both head originates from pharynx

16. In rabbit alveolar ducts originate from
(a) Bronchi (b) Trachea
(c) Bronchiole (d) Respiratory bronchiole

17. The cartilage present in the larynx of rabbit are **[BHU 2002]**
(a) Thyroid, cricoid, arytenoid
(b) Thyroid, cricoid, epiglottis
(c) Thyroid, cricoid, ethmoid
(d) Thyroid, cricoid, palatine

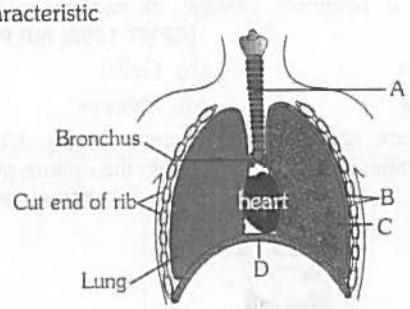
18. In which of the following animals Hb (Haemoglobin) is found dissolved in plasma **[CPMT 1998; DPMT 2007]**

Or

In which of the following animals, respiration occurs with out any respiratory organ **[CPMT 2003]**
(a) *Planaria* (b) Cockroach
(c) *Sepia* (d) Earthworm

19. The exchange of gases (O_2 and CO_2) in a mammal takes place in **[NCERT; CPMT 1992]**
(a) Trachea (b) Bronchi
(c) Bronchiole (d) Alveoli

20. The figure shows a diagrammatic view of human respiratory system with labels A, B, C and D. Select the option which gives correct identification and main function and/or characteristic



[NEET 2013]
(a) D – Lower end of lungs – diaphragm pulls it down during inspiration
(b) A – Trachea – long tube supported by complete cartilaginous rings for conducting inspired air
(c) B – Pleural membrane – surround ribs on both sides to provide cushion against rubbing
(d) C – Alveoli – thin walled vascular bag like structures for exchange of gases

21. Larynx is found in **[MP PMT 1992]**
(a) Both frog and rabbit (b) Neither frog nor rabbit
(c) Frog but not in rabbit (d) Rabbit but not in frog

22. The long trachea of rabbit contains **[CPMT 1992]**
(a) Buccal cord
(b) Thyroid
(c) Complete tracheal cartilage
(d) Incomplete tracheal cartilage

23. The right lung of rabbit has four lobes. They are **[CPMT 1992; MP PMT 1995]**
(a) Anterior lobe, anterior azygous, posterior lobe and right anterior
(b) Posterior lobe, posterior and anterior azygous, right anterior and right posterior
(c) Anterior azygous, right anterior, right posterior and posterior azygous lobe
(d) Anterior lobe, anterior azygous, right anterior and posterior azygous lobe

24. There is a membrane covering the lungs, called **[MP PMT 1994; KCET 1999; MH CET 2000; Pb. PMT 2004; AFMC 2005]**
(a) Peritonium (b) Pleura
(c) Pericardium (d) Duramater

25. In rabbit the lungs are lodged in **[CPMT 1992]**
(a) Thoracic cavity (b) Abdominal cavity
(c) Pleural cavity (d) Pericardial cavity

26. The most important function of diaphragm of the mammals is
(a) To divide the body cavity into compartment
(b) To protect lungs
(c) To aid in respiration
(d) To aid in ventilation

27. The pigment haemocyanin is found in **[BVP 2000; AIIMS 2000; CBSE PMT 2002; MHCET 2002]**
(a) Chordata (b) Annelida
(c) Mollusca (d) Echinodermata

28. Lung ventilation movements are due to **[Odisha JEE 2005]**
(a) Costal muscles and diaphragm
(b) Costal muscles
(c) Diaphragm
(d) Wall of the lungs

29. What is true about haemoglobin **[AIEEE Pharmacy 2006]**
(a) It is a dipeptide and present in red blood corpuscles in blood warm
(b) It is present in the dissolved state in blood plasma in earthworm
(c) It is a dipeptiede in mammals and localised in red blood corpuscles
(d) It is present in dissolved state in blood plasma in scorpions

30. The structure which prevents the entry of food into respiratory tract is
(a) Pharynx (b) Larynx
(c) Glottis (d) Epiglottis

31. In which animal, diaphragm has no role in respiration **[MH CET 2003]**
(a) Frog (b) Rat
(c) Camel (d) Rabbit

32. Thyroid is a cartilagenous plate in **[CPMT 1992, 93]**
(a) Skull of rabbit (b) Larynx of rabbit
(c) Vertebrae of rabbit (d) Sternum of rabbit

33. The diaphragm in rabbit is a **[J & K CET 2005]**
(a) Gap between the incisor and premolar teeth
(b) Membrane which surrounds and protects the brain
(c) Membrane which lies between the external auditory meatus and tympanic cavity of the ear
(d) Partition of muscular septum separating the thoracic cavity from abdominal cavity

Pulmonary volumes and capacities

1. What is vital capacity of our lungs **[CBSE PMT 2008]**
(a) Inspiratory reserve volume plus expiratory reserve volume
(b) Total lung capacity minus residual volume
(c) Inspiratory reserve volume plus tidal volume
(d) Total lung capacity *minus* expiratory reserve volume

2. The vital capacity of the lung signifies the volume of air
(a) Breathed in during normal inspiration
(b) Breathed out with forcible expiration
(c) Breathed in with forcible inspiration
(d) With deep inspiration and forcible expiration

3. Arrange the following in the order of increasing volume
(1) Tidal volume
(2) Residual volume
(3) Expiratory reserve volume
(4) Vital capacity **[NCERT; AIIMS 2007]**
(a) $1 < 2 < 3 < 4$ (b) $1 < 3 < 2 < 4$
(c) $1 < 4 < 3 < 2$ (d) $1 < 4 < 2 < 3$

4. The volume of air present in the lungs after forceful expiration is called as **[KCET 2006]**
(a) Tidal volume (b) Residual air
(c) Complementary air (d) None

5. The largest quantity of air that can be expired after a maximum inspiratory effort is **[NCERT; CPMT 1999; Pb. PMT 1999; CPMT 2004; MP PMT 2007; Odisha JEE 2011]**
(a) Residual volume (b) Tidal volume
(c) Vital capacity of lung (d) Lung volume

6. The volume of air which remains in the conducting airways and is not available for gas exchange is called **[J & K CET 2012]**
(a) Vital capacity
(b) Functional residual capacity
(c) Forced expiratory volume
(d) Anatomic dead space

7. How much amount of volume of air is in lungs FRC **[GUJCET 2015]**
(a) 1500 ml to 1600 ml (b) 2100 ml to 2500 ml
(c) 2500 ml to 3000 ml (d) 1600 ml to 2100 ml

8. The enzyme essential for the transport of CO_2 as bicarbonate in blood is **[MP PMT 2012; Kerala PMT 2012]**
(a) Carboxypeptidase (b) Succinic dehydrogenase
(c) Carbonic anhydrase (d) Thrombokinase
(e) Lactase

9. The amount of volume of air that can be inspired/expired normally is called **[DPMT 2007; AFMC 2009, 10; J & K CET 2010; GUJCET 2014]**
(a) Tidal volume (b) Vital capacity
(c) Residual volume (d) Normal volume

10. The area of inner surface of bronchiole is **[KCET 2001; MH CET 2003]**
(a) $1\ m^2$ (b) $10\ m^2$
(c) $100\ m^2$ (d) $1000\ m^2$

11. Capacity of human lung for air **[Odisha JEE 2005]**
(a) 3000 *ml* (b) 1500 *ml*
(c) 1000 *ml* (d) 500 *ml*

12. Residual volume is **[KCET 2007]**
(a) Lesser than tidal volume
(b) Greater than inspiratory volume
(c) Greater than vital capacity
(d) Greater than tidal volume

13. Vital capacity of the lung includes **[Kerala PMT 2007; DPMT 2007; BHU 2012]**

Or

After forceful inspiration, the amount of air that can be breathed out by maximum forced expiration is equal to **[WB JEE 2012]**
(a) $IRV + TV + ERV$ (b) $ERV + RV$
(c) $ERV + TV$ (d) $IRV + TV$
(e) $RV + ERV + TV + IRV$

14. Match the items in Column – I with Column – II and choose the correct option

Column – I		Column – II	
A.	Tidal volume	1.	2500 to 3000 *ml* of air
B.	Inspiratory reserve volume	2.	1000 *ml* of air
C.	Expiratory reserve volume	3.	500 *ml* of air
D.	Residual volume	4.	3400 to 4800 *ml* of air
E.	Vital capacity	5.	1200 *ml* of air

[NCERT; CBSE PMT 1996; Pb PMT 2004; Kerala PMT 2007; AFMC 2012]
(a) A – 3, B – 4, C – 2, D – 1, E – 5
(b) A – 3, B – 1, C – 2, D – 5, E – 4
(c) A – 3, B – 1, C – 4, D – 5, E – 4
(d) A – 5, B – 4, C – 2, D – 1, E – 2
(e) A – 4, B – 3, C – 2, D – 1, E – 5

15. The partial pressure of oxygen in the alveolar air is **[Kerala PMT 2010]**
(a) 45 *mm Hg* (b) 95 *mm Hg*
(c) 104 *mm Hg* (d) 110 *mm Hg*
(e) 125 *mm Hg*

16. The volume of 'anatomical dead space' air is normally **[WB JEE 2012]**
(a) 230 *ml* (b) 210*ml*
(c) 190*ml* (d) 150 *ml*

17. The volume and surface area of a deer is 1,50,000 cm^3 and 19,000 cm^2 and of a squirrel is 625 cm^3 and 530 cm^2. The area available for heat loss per cm^3 volume of the squirrel will be approximately **[AMU (Med.) 2010]**
(a) Seven times more than the deer
(b) Five times less than the deer
(c) Three times more than the deer
(d) Eleven times more than the deer

18. The urge to inhale in humans results from **[DUMET 2010]**
(a) Rising PCO_2 (b) Rising PO_2
(c) Falling PCO_2 (d) Falling PO_2

19. Listed below are four respiratory capacities $(A - D)$ and four jumbled respiratory volumes of a normal human adult

Respiratory capacities		Respiratory volumes
(A) Residual volume	-	2500 *mL*
(B) Vital capacity	-	3500 *mL*
(C) Inspiratory reserve volume	-	1200 *mL*
(D) Inspiratory capacity	-	4500 mL

Which one of the following is the correct matching of two capacities and volumes **[CBSE PMT (Pre.) 2010]**
(a) (A) 4500 *mL*, (B) 3500 *mL*
(b) (B) 2500 *mL*, (C) 4500 *mL*
(c) (C) 1200 *mL*, (D) 2500 *mL*
(d) (D) 3500 *mL*, (A) 1200 *mL*

20. Complete and balanced the following reaction

$Na_2HPO_4 + X \rightarrow Y + NaH_2PO_4$ **[GUJCET 2015]**

(a) X = $NaHCo_3$, Y = NaCl

(b) X = H_2CO_3, Y = NaH_2CO_3

(c) X = $NaHCO_3$, Y = H_2CO_3

(d) X = H_2CO_3, Y = $NaHCO_3$

21. Lungs are made up of air-filled sacs, the alveoli. They do not collapse even after forceful expiration because of **[NEET 2017]**

(a) Residual Volume (b) Inspiratory Reserve Volume

(c) Tidal Volume (d) Expiratory Reserve Volume

Process of respiration

1. Oxy-haemoglobin dissociates into oxygen and deoxy-haemoglobin at**[DPMT 1992; MP PMT 1995; JIPMER 2002]**

(a) Low O_2 pressure in tissue

(b) High O_2 pressure in tissue

(c) Equal O_2 pressure inside and outside tissue

(d) All times irrespective of O_2 pressure

2. In lungs, the air is separated from the venous blood through **[CBSE PMT 1997]**

(a) Squamous epithelium + endothelium of blood vessel

(b) Squamous epithelium + tunica media blood vessel

(c) Transitional epithelium + tunica external blood vessel

(d) None of these

3. The exchange of gases in the alveoli of the lungs takes place by **[CBSE PMT 1998; AFMC 2002; Bihar BCECE 2005; Odisha JEE 2010]**

(a) Osmosis (b) Simple diffusion

(c) Passive transport (d) Active transport

4. Which of the following enzymes is absent in mitochondria **[CPMT 1998]**

(a) Aconitase (b) Maleic dehydrogenase

(c) Hexokinase (d) None of these

5. If concentration of CO_2 is more the curve of oxygen will shift towards **[MP PMT 2002]**

Or

Increase in body temperature makes oxygen haemoglobin dissociation curve shift to **[BHU 2012]**

(a) Right (b) Left

(c) Central (d) None of these

6. The respiratory substrate yielding maximum number of ATP molecules among the following is **[CBSE PMT 1994]**

(a) Glycogen (b) Amylase

(c) Ketogenic amino acid (d) Glucose

7. Division of mammalian lungs into a very large number of tiny alveoli around alveolar ducts opening into bronchioles, is **[CBSE PMT 1995]**

(a) An inefficient system of ventilation of alveoli though with very little residual air

(b) An inefficient system of ventilating the alveoli resulting in very high percentage of residual air in the lungs

(c) A very efficient system of ventilating the alveoli with no residual air

(d) An efficient system of ventilation of alveoli with little or no residual air

8. Choose the right sequential phenomena among the following during the delivery of O_2 from blood to tissue

P. Absorption of CO_2 by the blood

Q. Reaction of absorbed CO_2 with H_2O to from H_2CO_3 within RBC and its conversion into H^+ and HCO_3^- ions

R. Reaction of absorbed CO_2 with H_2O in plasma to form H_2CO_3 and its conversion into H^+ and HCO_3^- ions

S. Combination of H^+ with haem portion of HbO_2 to release O_2

T. Combination of HCO_3^- with haem portion HbO_2 to form reduced haemoglobin and release of O_2

[WB JEE 2012]

(a) P, Q, T (b) P, R, S

(c) P, Q, S (d) P, R, T

9. The alveoli of lungs are lined by **[Kerala PMT 2008]**

(a) Simple epithelium (b) Squamous epithelium

(c) Cuboidal epithelium (d) Columnar epithelium

(e) Ciliated epithelium

10. Which of the following is used for long term energy storage by animals **[Odisha JEE 2009]**

(a) Amino acids (b) Glucose

(c) Fat (d) Glycogen

11. Intra aortic balloon pump is inflated by **[JIPMER 2002]**

(a) Hydrogen (b) Oxygen

(c) Helium (d) Chlorine

12. Energy is stored in the liver and muscles in the form of **[CPMT 1998; MP PMT 1999; AFMC 2003; Odisha JEE 2009]**

Or

In the muscles carbohydrates are stored in the form of **[WB JEE 2016]**

(a) Carbohydrates (b) Glycogen

(c) Fat (d) Protein

13. The major fraction of CO_2 released during cellular respiration is transported by the blood to the lung capillaries **[NCERT; CPMT 1998; MP PMT 1998, 2002; AIEEE Pharmacy 2003; Odisha JEE 2010]**

Or

Approximately seventy percent of carbon-dioxide absorbed by the blood will be transported to the lungs **[CBSE PMT 2014]**

(a) In combination with haemoglobin

(b) As free CO_2

(c) As carbonic acid or H_2CO_3

(d) In the form of bicarbonate ions

14. The amount of O_2 transported in a dissolved state through plasma is approximately **[NCERT; Kerala PMT 2012]**

(a) 97% (b) 20 – 25%

(c) 7% (d) 49%

(e) 3%

15. During inspiration the diaphragm **[BHU 2004; CPMT 2010]**

(a) Relaxes to become dome-shaped

(b) Contracts and flattens

(c) Expands

(d) Shows no change

16. In hurdle race, which of the following is accumulated in the leg muscle **[DUMET 2009]**
(a) Performed ATP (b) Glycolysis
(c) Lactate (d) Oxidative metabolism

17. Which of the following sets is most correct for the catabolism of an 18 carbon fatty acid **[AMU (Med.) 2009]**
(a) Mitochondria, beta-oxidation, 140 ATP molecules
(b) Cytosol, beta oxidation, 146 ATP molecules
(c) Mitochondria, beta oxidation, 146 ATP molecules
(d) Cytosol, beta oxidation, 140 ATP molecules

18. In humans, which among these is not a step in respiration **[NCERT; Kerala PMT 2012]**
(a) Pulmonary ventilation
(b) Alveolar diffusion of O_2 and CO_2
(c) Transport of gases by blood
(d) Diffusion of O_2 and CO_2 between blood and tissues
(e) Utilization of CO_2 by cells for catabolic reactions

19. *Hb* is a **[MP PMT 2007]**
(a) Reproductive pigment (b) Respiratory pigment
(c) Carbohydrate (d) Fat

20. According to Boyle's law, the product of pressure and volume is a constant. Hence, **[KCET 2010]**
(a) If volume of lungs is increased, the pressure decreases, proportionately
(b) If volume of lungs is increased, the pressure also increases proportionately
(c) If volume of lungs is increased, the pressure decreases disproportionately
(d) If volume of lungs is increased, the pressure remains the same

21. Chloride shift occurs in respond to **[DPMT 2007]**
(a) H^+ (b) K^+
(c) HCO_3^- (d) Na^+

22. Which one of the following is a possibility for most of us in regards to breathing, by making a conscious effort **[NCERT; CBSE PMT (Mains) 2011]**
(a) One can consciously breathe in and breathe out by moving the diaphragm alone, without moving the ribs at all
(b) The lungs can be made fully empty by forcefully breathing out all air from them
(c) One can breathe out air totally without oxygen
(d) One can breathe out air through eustachian tubes by closing both the nose and the mouth

23. Identify the correct statement with reference to transport of respiratory gases by blood **[KCET 2006]**
(a) Haemoglobin is necessary for transport of carbon dioxide and carbonic anhydrase for transport of oxygen
(b) Haemoglobin is necessary for transport of oxygen and carbonic anhydrase for transport of carbon dioxide
(c) Only oxygen is transported by blood
(d) Only carbon dioxide is transported by blood

24. Which of the following statement correctly defines "Bohr effects"
(a) Rise in PCO_2 with a decrease in CO_2 concentration
(b) Rise in PCO_2 with an increase in CO_2 concentration
(c) Rise in PCO_2 with an increase in CO_2 and decrease in PO_2
(d) Rise in PCO_2 with a decrease in pH (concentration at which 50% haemoglobin of blood is saturated with oxygen)

25. Under a given concentration in blood, dissociation of oxyhaemoglobin will increase if
(a) pH of blood falls
(b) pH of blood rises
(c) CO_2 concentration in blood falls
(d) Free fatty acid concentration in blood falls

26. Oxygen binding to haemoglobin in blood is **[AIIMS 2012]**
(a) Directly proportional to the concentration of CO_2 in the medium
(b) Inversely proportional to the concentration of CO_2 in the medium
(c) Directly proportional to the concentration of CO in the medium
(d) Independent of the concentration of CO in the medium

27. Bulk of carbon dioxide (CO_2) released from body tissues into the blood is present as **[NCERT; CBSE PMT (Mains) 2011]**
(a) 70% carbamino-haemoglobin and 30% as bicarbonate
(b) Carbamino-haemoglobin in RBCs
(c) Bicarbonate in blood plasma and RBCs
(d) Free CO_2 in blood plasma

28. O_2 dissociation curve is **[NCERT; BHU 1995, 2000; CPMT 2000; DPMT 2007]**
(a) Sigmoid (b) Slope
(c) Straight line (d) Parabola

29. In expiration condition, diaphragm becomes **[CPMT 1993]**
(a) Circular (b) Relaxed
(c) Fully contracted (d) Expanded

30. Maximum amount of oxygen is lost from the blood in the **[KCET 2006]**
(a) Capillaries surrounding the tissue cells
(b) Arteries of the body
(c) Capillaries surrounding the alveoli
(d) Left auricle of the heart

31. Which of the following activity does not take place during pulmonary respiration **[Bihar MDAT 1995]**
(a) Movement of buccal cavity
(b) Contraction and relaxation of sternohyal and pterohyal muscles
(c) Successive opening and closing of mouth and external nostrils
(d) All the above
(e) No activity takes place

32. In anaerobic respiration the pyruvic acid in muscle will form **[CPMT 1995, 99; AFMC 2002, 08; DPMT 2003]**
(a) Lactic acid ($C_3H_6O_3$) and H_2O
(b) Alcohol (C_2H_5OH) and H_2O
(c) Acetaldehyde and H_2O
(d) Acetyl *CoA* and H_2O

33. Blood contains CO_2 in which of the following forms
(a) $NaHCO_3$ (b) Carbonic acid
(c) $Hb-CO_2$ (d) $Hb-CO_2$ and CO

34. Oxygen is transported to every cell of the body through **[MP PMT 1994]**
(a) RBC (b) WBC
(c) RBC and WBC (d) RBC and hormones

35. Acquiring an oxygen debt is evidence that **[CPMT 2005]**
(a) O_2 cannot be stored in tissue
(b) Aerobic respiration is more complex than glycolysis
(c) Lactic acid can be converted into glycogen
(d) Anaerobic process are slower than aerobic processes

36. The dissociation curve is associated with **[NCERT]**
(a) Oxygen (b) Oxyhaemoglobin
(c) Carbon dioxide (d) Carbonic anhydrase

37. Respiratory system is derived from **[CPMT 1993]**
(a) Ectoderm (b) Mesoderm
(c) Endoderm (d) None of these

38. The breakdown product of haemoglobin is called as **[CBSE PMT 1993]**
(a) Iron (b) Bilirubin
(c) Haemocynin (d) Skatol

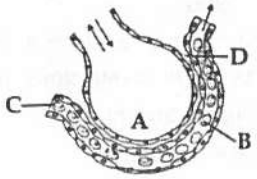
39. During respiration CO_2 is transported in the form of **[NCERT; CBSE PMT 1995, 2006; AFMC 2006, 10; BHU 2006]**
(a) Dissolved plasma
(b) Sodium carbonate
(c) $KHCO_3$
(d) Partly dissolved in plasma and partly in the form of sodium and potassium bicarbonate

40. CO_2 is dissolved in haemoglobin or blood plasma as **[CBSE PMT 1993; WB JEE 2016]**
(a) Carbonates (b) Bicarbonates
(c) Oxyhaemoglobin (d) Carboxyhaemoglobin

41. The factor which does not affect the rate of alveolar diffusion is **[NCERT; Kerala PMT 2011]**
(a) Solubility of gases (b) Thickness of the membranes
(c) Pressure gradient (d) Concentration gradient
(e) Reactivity of the gases

42. In Bhor's effect curve shift to right **[Bihar CECE 2006]**
(a) P_{50} CO_2 decreases and P_{50} O_2 increases
(b) P_{50} CO_2 increases and P_{50} O_2 decreases
(c) P_{50} CO_2 increases and P_{50} O_2 increases
(d) P_{50} CO_2 increases and P_{50} O_2 decreases and pH increases

43. The figure given below shows a small part of human lung where exchange of gases takes place. In which one of the option given below, the one part A, B, C or D is correctly identified along with its functions



Options **[CBSE PMT (Pre.) 2011]**
(a) B : Red blood cell – transport of CO_2 mainly
(b) C : Arterial capillary – passes oxygen to tissues
(c) A : alveolar cavity – main site of exchange of respiratory gases
(d) D : Capillary wall – exchange of O_2 and CO_2 takes place here

44. Reduction in pH of blood will **[NEET (Phase-I) 2016]**
(a) Reduce the rate of heart beat
(b) Reduce the blood supply to the brain
(c) Decrease the affinity of hemoglobin with oxygen
(d) Release bicarbonate ions by the liver

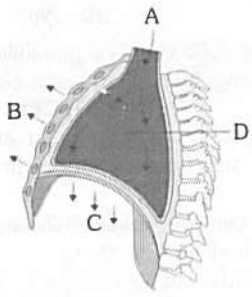
45. When you hold your breath, which of the following gas changes in blood would first lead to the urge to breathe **[AIPMT (Cancelled) 2015]**
(a) Rising CO_2 concentration
(b) Falling CO_2 concentration
(c) Rising CO_2 and falling O_2 concentration
(d) Falling O_2 concentration

46. In lungs there is definite exchange of ions between RBC and plasma. Removal of CO_2 from blood involves **[CPMT 2005]**
(a) Influx of Cl^- ions into RBC
(b) Influx of HCO_3^- ions into RBC
(c) Efflux of Cl^- ions into RBC
(d) Efflux of HCO_3^- ions into RBC

47. In a minute normal man respires **[NCERT; MP PMT 1993]**
(a) 10 times (b) 16 times
(c) 30 times (d) 4 times

48. The process by which chloride ions pass into R.B.C. and bicarbonate ions pass out is called **[DPMT 1992; RPMT 1999; Kerala CET 2003]**
(a) Bicarbonate shift (b) Chloride shift
(c) Buffer system (d) Enzyme shift

49. Following diagram indicates the mechanism of breathing. Identify all the parts A, B, C and D correctly **[NCERT]**



(a) A – Air expelled from lungs; B – Ribs and sternum raised; C – Diaphragm contracted; D – Volume of thorax decreased
(b) A – Air expelled from lungs; B – Ribs and sternum raised; C – Diaphragm relaxed; D – Volume of thorax decreased
(c) A – Air expelled from lungs; B – Ribs and sternum return to original position; C – Diaphragm relaxed; D – Volume of thorax decreased
(d) A – Air entering into lungs; B – Ribs and sternum raised; C – Diaphragm contracted; D – Volume of thorax raised

50. Muscles which help in respiration are
(a) Sternum and petrohyal (b) Sternohyal and petrohyal
(c) Jugal and tendons (d) None of these

51. Of the following, the one which is an example of buffer system in blood is **[Kerala PMT 2004]**
(a) Haemoglobin and oxyhaemoglobin
(b) Oxygen and carbon dioxide
(c) Albumin and globulin
(d) Sodium bicarbonate and carbonic acid

52. In a normal man to help the transport of O_2 and CO_2 properly, the blood is
(a) Slightly alkaline (b) Slightly acidic
(c) Strongly alkaline (d) Strongly acidic

53. In mammals how much CO_2 is transported as bicarbonates of sodium and potassium in the blood **[AIIMS 1993]**
(a) 5–10 % (b) 10–90 %
(c) 70–72 % (d) 90–95 %

54. A large proportion of oxygen is left unused the human blood even after its uptake by the body tissue. This O_2 **[NCERT; CBSE PMT (Pre.) 2011]**
(a) Helps in releasing more O_2 to the epithelium tissues
(b) Acts as a reserve during muscular exercise
(c) Raises the pCO_2 of blood to 75 mm of Hg
(d) Is enough to keep oxyhaemoglobin saturation at 96%

55. Chloride shift is essential for the transport of **[CBSE PMT 1990]**
(a) CO_2 and O_2 (b) N_2
(c) CO_2 (d) O_2

56. Which is true for CO_2 concentration **[Odisha JEE 2004]**
(a) More in alveolar air than in expired air
(b) More in expired air than in alveolar air
(c) More in inspired air than in expired air
(d) More in inspired air than in alveolar air

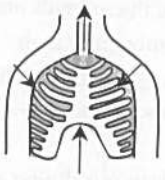
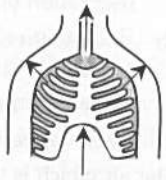
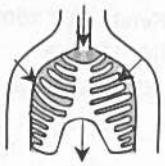
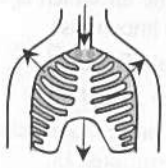
57. The two waste products of oxidation in cells are
(a) CO_2 and N_2 (b) C and O
(c) CO_2 and water (d) Water and N_2

58. The function of tracheal hair is to **[BVP 2003]**
(a) Pass mucus out (b) Pass mucus in
(c) Pass air out (d) Pass air in

59. The function of surfactant is/are **[J & K CET 2012]**
(a) Facilitating lung expansion
(b) Maintaining the stable size of the alveoli
(c) To reduce the surface tension on the alveoli
(d) All the above

60. During cellular respiration the energy produced is stored in
Or
The common immediate source of energy in cellular activity
(a) Protoplasm (b) Cytoplasm
(c) ATP (d) Nucleus

61. Exhalation is the process of expulsion of air through the respiratory tract. Which figure correctly shows the process of exhalation **[NCERT]**

(a) 
(b) 
(c) 
(d) 

62. Respiration is the physiological process in which
(a) Breathing occurs
(b) Breathing and external respiration occur
(c) Breathing, external respiration and cellular respiration occur
(d) Only inspiration occurs

63. In rabbit the inspiration occurs by contraction of
(a) External intercostal muscles and muscles of the diaphragm
(b) Internal intercostal muscles and muscles of the diaphragm
(c) External intercostal muscles only
(d) Muscles of the diaphragm only

64. Left shift of oxyhaemoglobin curve is noticed under **[EAMCET 2009]**
(a) Normal temperature and *pH*
(b) Low temperature and high *pH*
(c) Low *pH* and high temperature
(d) Low *pH* and low temperature

65. Lungs do not collapse between breaths and some air always remains in the lungs which can never be expelled because **[NEET (Phase-II) 2016]**
(a) Pressure in the lungs is higher than the atmospheric pressure
(b) There is a negative pressure in the lungs
(c) There is a negative intrapleural pressure pulling at the lung walls
(d) There is a positive intrapleural pressure

66. The partial pressure of oxygen in the alveoli of the lungs is **[NEET (Phase-II) 2016]**
(a) Less than that of carbon dioxide
(b) Equal to that in the blood
(c) More than that in the blood
(d) Less than that in the blood

Control of breathing

1. How much amount of air can be inspired or expired during normal breathing **[DPMT 2003; BVP 2004]**
(a) 0.5 *l* (b) 2.5 *l*
(c) 1.5 *l* (d) 5.5 *l*

2. Breathing differs from respiration by [AFMC 1993]
(a) Both are same and there is no difference
(b) Breathing refers to respiration in human beings whereas respiration occurs in rest of the animals and plants
(c) Breathing refers to chest movements due to inhalation of O_2 and exhalation of carbon dioxide whereas respiration refers to gaseous exchange
(d) None of these

3. The air which is taken in or given out during a single breath is known as [Kerala CET 2002; BHU 2008]
(a) Residual air (b) Vital air
(c) Tidal air (d) All of these

4. Combination of haemoglobin with O_2 in lungs can be promoted by [MP PMT 2006]
(a) Increasing CO_2 concentration in blood
(b) Increasing O_2 concentration in blood
(c) Decreasing O_2 concentration in blood
(d) Introducing CO in blood

5. Step of respiration are controlled by [RPMT 2005]
(a) Substrates (b) Enzymes
(c) Hormone (d) Bile juice

6. Respiration mechanism is controlled by
(a) Central nervous system
(b) Autonomic nervous system
(c) Sympathetic nervous system
(d) Parasympathetic nervous system

7. Which of the following conditions is responsible for increase in ventilation rate of lungs [CPMT 2005]
(a) Increase of CO_2 content in inhaled air
(b) Increase of CO_2 content in exhaled air
(c) Decrease of O_2 content in inhaled air
(d) Decrease of O_2 content in exhaled air

8. The respiratory centre in brain which controls inspiration and expiration is situated in [CPMT 1993, 99; CBSE PMT 1994, 99; BHU 1995; AFMC 1995; RPMT 1995, 99, 2005, 06; MP PMT 1996; Pb. PMT 1999; AIIMS 2001; Kerala PMT 2010]

Or

Respiratory and vomitting centres are located in [NCERT; MH CET 2002; DUMET 2009]
(a) Medulla oblongata (b) Cerebellum
(c) Hypothalamus (d) Pericardium

9. When CO_2 concentration in blood increases, breathing becomes [CPMT 2004]
(a) Slow and deep
(b) Faster and deeper
(c) Shallower and slow
(d) There is no effect on breathing

10. Respiratory centre of brain is sensitive to [NCERT; Odisha JEE 2004]
(a) More O_2 conc. in blood
(b) More CO_2 conc. in blood
(c) Accumulation of blood in brain
(d) All of these

11. A substance that prevents or delays oxidation is [J & K CET 2005]
(a) Bactericidal (b) Hormone
(c) Antioxidant (d) Enzyme

12. Rate of breathing is controlled by [Kerela CET 2005]
(a) The amount of freely available oxygen
(b) Carbon dioxide
(c) Muscular function of the body
(d) Stress

Important concepts of respiration

1. What is R.Q. for human fat [DPMT 1992]
(a) 0.673 (b) 0.655
(c) 0.703 (d) 0.825

2. The form of energy used in respiration is [CPMT 1993]
(a) Chemical energy (b) Electrical energy
(c) Mechanical energy (d) Radiant energy

3. In human blood, the oxygen carrier is [CPMT 1994]
(a) Iron (b) Meth–haemoglobin
(c) Haemocyanin (d) Haemoglobin

4. The toxic effect of carbon monoxide is due to its greater affinity for haemoglobin as compared to oxygen, approximately by [BHU 2002]
(a) 2 times (b) 20 times
(c) 200 times (d) 1000 times

5. During strenous exercise, which of the following change occurs [CPMT 2000]
(a) Glucose is converted into glycogen
(b) Glucose is converted into pyruvic acid
(c) Starch is converted into glucose
(d) Pyruvic acid is converted into lactic acid

6. Which of the following blood vessels in the circulatory system of frog has more oxygenated blood [AFMC 2006]
(a) Pulmocutaneous artery (b) Pulmocutaneous vein
(c) Pulmonary artery (d) Precaval veins

Disorders of respiration system

1. After fast running, man has fast heart beat, slow pulse and shallow breathing, in such conditions he has
(a) Oxygen debt
(b) Poisoning due to lactic acid
(c) No pulmonary pressure
(d) Weak heart

2. Increased asthmatic attacks in certain seasons are related to [CBSE PMT 2007; MP PMT 2013]
(a) Hot and humid environment
(b) Eating fruits preserved in tin containers
(c) Inhalation of seasonal pollen
(d) Low temperature

3. After taking a long deep breath we do not respire for some seconds due to [BHU 2005]
(a) More CO_2 in blood (b) More O_2 in blood
(c) Less CO_2 in blood (d) Less O_2 in blood

4. Ascent of high mountains may cause altitude sickness in men. Prime cause of this is [NCERT; CPMT 2005]
(a) Excess of CO_2 in blood
(b) Decreased efficiency of haemoglobin
(c) Decreased partial pressure of oxygen
(d) Decreased proportion of oxygen in air

5. The state during which the respiratory centre is inhibited is termed as **[DPMT 1993]**
(a) Asphyxia (b) Suffocation
(c) Anoxia (d) Chocking

6. Ravi, who lived at sea level, had around 5 million RBC per cubic millimeter of his blood. Later when he lived at an altitude of 18,000 ft, showed around 8 million RBC per cubic millimeter of blood. This is an adaptation because **[AIEEE Pharmacy 2004; RPMT 2005]**
(a) At high altitude he ate more nutritive food
(b) He had pollution free air to balance breathe
(c) At high altitude O_2 level is less hence more RBCs were required to absorb enough oxygen
(d) At high altitude there is more UV radiation which enhances RBCs production

7. During rest, the metabolic needs of the body are at their minimum. Which of the following is indicative of this situation **[AFMC 1994]**
(a) Rate of breathing (b) Pulse rate
(c) O_2 intake and CO_2 output (d) All of these

8. Cyanosis is
(a) Lack of oxygen in body fluids
(b) Difficult or heavy breathing
(c) Excess of carbon dixode in the body fluids
(d) 'Skin turning blue' due to excessive amount of deoxygenated haemoglobin in the skin blood vessels

9. Pneumotaxis centre is associated with
(a) Breathing (b) Respiration
(c) Movement (d) Closure of glottis

10. Congestion of the lungs is one of the main symptoms in **[Kerala PMT 2011]**
(a) Hypotension (b) Coronary artery disease
(c) Angina (d) Heart failure
(e) Atherosclerosis

11. When O_2 is inadequate during respiration. the condition is called **[BVP 2000; WB JEE 2011; Odisha JEE 2012]**
(a) Anoxia (b) Pleurisy
(c) Asphyxia (d) Hypoxia

12. The oxygen toxicity is related with **[BHU 2004]**
(a) Blood poisoning
(b) Collapse of alveolar walls
(c) Failure of ventilation of lungs
(d) Both (a) and (b)

13. The diabetic patient shows
(a) High respiratory quotient (b) Low respiratory quotient
(c) Zero respiratory quotient (d) None of these

14. The 'blue baby' syndrome results from **[CBSE PMT 2006]**
(a) Excess of dissolved oxygen
(b) Excess of TDS (total dissolved solids)
(c) Excess of chloride
(d) Methaemoglobin

15. Asthma is characterised by **[NCERT; Odisha JEE 2011]**
(a) Spasm in bronchial muscle
(b) Alveolar wall degradation
(c) Pain in lungs
(d) Damage in diaphragm

16. In which disease, due to flattening of tracheal vessels, alveoli are deprived of oxygen **[NCERT; GUJCET 2007]**

Or

Name the pulmonary disease in which alveolar surface area involved in gas exchange is drastically reduced due to damage in the alveolar walls **[AIPMT 2015]**
(a) Bronchitis (b) Asthma
(c) Pneumonia (d) Emphysema

17. Blood analysis of a patient reveals an unusually high quantity of carboxyhaemoglobin content. Which of the following conclusions is most likely to be correct **[CPMT 2004]**
(a) Carbon dioxide (b) Carbon monoxide
(c) Carbon disulphide (d) Chloroform

NCERT Exemplar Questions

1. Respiration in insects is called direct because **[NCERT]**
(a) The tissues exchange O_2/CO_2 directly with the air in the tubes
(b) The tissues exchange O_2/CO_2 directly with coelomic fluid
(c) The tissues exchange O_2/CO_2 directly with the air outside through body surface
(d) Tracheal tubes exchange O_2/CO_2 directly with the haemocoel which then exchange with tissues

2. Regarding the functions of our respiratory system, mark the wrong entry **[NCERT]**
(a) Humidifies the air (b) Warms up the air
(c) Diffusion of gases (d) Cleans up the air

3. A person suffers punctures in his chest cavity in an accident, without any damage to the lungs its effect could be **[NCERT]**
(a) Reduced breathing rate
(b) Rapid increase in breathing rate
(c) No change in respiration
(d) Cessation of breathing

4. Mark the true statement among the following with reference to normal breathing **[NCERT]**
(a) Inspiration is a passive process where as expiration is active
(b) Inspiration is a active process where as expiration is passive
(c) Inspiration and expiration are active processes
(d) Inspiration and expiration are passive processes

5. A person breathes in some volume of air by forced inspiration after having a forced expiration. This quantity of air taken in is **[NCERT]**
(a) Total lung capacity (b) Tidal volume
(c) Vital capacity (d) Inspiratory capacity

6. Mark the incorrect statement in context to O_2 binding to Hb **[NCERT]**
(a) Higher pH (b) Lower temperature
(c) Lower pCO_2 (d) Higher PO_2

7. Mark the correct pair of muscles involved in the normal breathing in humans [NCERT]
   (a) External and internal intercostals muscles
   (b) Diaphragm and abdominal muscles
   (c) Diaphragm and external intercostals muscles
   (d) Diaphragm and internal intercostals muscles

8. Incidence of Emphysema – a respiratory disorder is high in cigarette smokers. In such cases [NCERT]
   (a) The bronchioles are found damaged
   (b) The alveolar walls are found damaged
   (c) The plasma membrane is found damaged
   (d) The respiratory muscles are found damaged

9. Respiratory process is regulated by certain specialized centres in the brain. One of the following listed centres can reduce the inspiratory duration upon stimulation [NCERT]
   (a) Medullary inspiratory centre (b) Pneumotaxic centre
   (c) Apneustic centre (d) Chemosensitive centre

10. CO_2 dissociates from carbamino haemoglobin when [NCERT]
   (a) pCO_2 is high and pO_2 is low
   (b) pO_2 is high and pCO_2 is low
   (c) pCO_2 and pO_2 are equal
   (d) None of the above

11. Identify the correct and incorrect match about respiratory volume and capacities and mark the correct answer
   (i) Inspiratory capacity (IC) = Tidal Volume + Residual volume
   (ii) Vital Capacity (VC) = Tidal Volume (TV) + Inspiratory Reserve Volume (IRV) + Expiratory Reserve Volume (ERV)
   (iii) Residual Volume (RV) = Vital Capacity (VC) – Inspiratory Reserve Volume (IRV)
   (iv) Tidal Volume (TV) = Inspiratory Capacity (IC) – Inspiratory Reserve Volume (IRV)
   Options: [NCERT]
   (a) (i) Incorrect, (ii) Incorrect, (iii) Incorrect, (iv) Correct
   (b) (i) Incorrect, (ii) Correct, (iii) Incorrect, (iv) Correct
   (c) (i) Correct, (ii) Correct, (iii) Incorrect, (iv) Correct
   (d) (i) Correct, (ii) Incorrect, (iii) Correct, (iv) Incorrect

12. The oxygen – haemoglobin dissociation curve will show a right shift in case of [NCERT]
   (a) High pCO_2 (b) High pO_2
   (c) Low pCO_2 (d) Less H^+ concentration

13. Match the following and mark the correct options

Animal	Repiratory organ
A. Earthworm	i. Moist cuticle
B. Aquatic Arthropods	ii. Gills
C. Fishes	iii. Lungs
D. Birds/Reptiles	iv. Trachea

   Options [NCERT]
   (a) A-ii, B-i, C-iv, D-iii (b) A-i, B-iv, C-ii, D-iii
   (c) A-i, B-iii, C-ii, D-iv (d) A-i, B-ii, C-iv, D-iii

CT Critical Thinking

Objective Questions

1. Which animal has unpaired lungs
   (a) Monkey (b) Whale
   (c) Some frogs (d) Some snakes

2. Mammalian lungs have enormous number of minute alveoli (air sacs). It is to allow [AFMC 1994; MP PMT 1995]
   (a) More space for increasing the volume of inspired air
   (b) More surface area for diffusion of gases
   (c) More spongy texture for keeping lungs in proper shape
   (d) More nerve supply to keep organs active when working

3. True organ of sound production in birds is [Kerala CET 2003]
   (a) Larynx (b) Sound box
   (c) Vocal sac (d) Syrinx

4. The nerve impulses which stimulate the intercostal muscles and diaphragm and thus permit breathing, originate in the [AIIMS 1992]
   (a) Cerebellum (b) Pons
   (c) Hypothalamus (d) Medulla oblongata

5. Number of alveoli in human lung is about [Odisha JEE 2012]
   (a) One million (b) More than two millions
   (c) More than five millions (d) More than seven millions

6. Which of the following statements is not true [Kerala PMT 2007]
   (a) The partial pressure of oxygen in deoxygenated blood is 40 *mm Hg*
   (b) The partial pressure of oxygen in oxygenated blood is 95 *mm Hg*
   (c) The partial pressure of oxygen in the alveolar air is 104 *mm Hg*
   (d) The partial pressure of carbon dioxide in the alveolar air is 40 *mm Hg*
   (e) The partial pressure of carbon dioxide in deoxygenated blood is 95 *mm Hg*

7. Which option is completely correct for the given statements
   Statement 1 – The nerve impulse ordered by respiratory centre passes through nerve to the diaphragm and the intercostal muscles and regulates respiration
   Statement 2 – Respiratory centres scatterly located in the brain stem gives of rhythmic stimuli to diaphragm and respiratory muscle and regulate respiration [GUJCET 2014]
   (a) First statement is correct and second statement is wrong
   (b) First statement is wrong and second statement is correct
   (c) Both of the statements are wrong
   (d) Both of the statements are correct

8. The impulse for voluntary muscles for forced breathing starts in
   (a) Medulla (b) Vagus nerve
   (c) Cerebrum (d) Cerebellum

9. How much CO_2 is present per 100 *ml* of venous blood
(a) 52.1 *ml* (b) 3.7 *ml*
(c) 40 *ml* (d) 20 *ml*

10. Which of the following statements are true / false
A. The blood transports CO_2 comparatively easily because of its higher solubility
B. Approximately 8.9% of CO_2 is transported being dissolved in the plasma of blood
C. The carbon dioxide produced by the tissues, diffuses passively into the blood stream and passes into red blood corpsucles and react with water to form H_2CO_3
D. The oxyhaemoglobin (HbO_2) of the erythrocytes is basic
E. The chloride ions diffuse from plasma into the erythrocytes to maintain ionic balance
[Kerala PMT 2006]
(a) *A*, *C* and *E* are true, *B* and *D* are false
(b) *A*, *C* and *E* are false, *B* and *D* are true
(c) *A*, *B* and *D* are true, *C* and *E* are false
(d) *A*, *B* and *D* are false, *C* and *E* are true
(e) *A*, *B* and *C* are true, *D* and *E* are false

11. Which one of the following is the correct statement for respiration in humans **[NCERT; CBSE PMT (Pre.) 2012]**
(a) Cigarette smoking may lead to inflammation of bronchi
(b) Neural signals from pneumotoxic centre in pons region of brain can increase the duration of inspiration
(c) Workers in grinding and stone-breaking industries may suffer, from lung fibrosis
(d) About 90% of carbon dioxide (CO_2) is carried by haemoglobin as carbamino haemoglobin

12. Concentration of carbonic acid does not increase in blood due to the presence of
(a) Na^+ (b) K^+
(c) Ca^{++} (d) Mg^{++}

13. A pyrophosphate cleavage takes place when **[CPMT 1998]**
(a) ATP is converted into AMP
(b) ATP is converted into ADP
(c) ADP is converted into AMP
(d) AMP is converted into ATP

14. Haemoglobin is having maximum affinity with
[CPMT 1995; MP PMT 1999; RPMT 1999]
(a) CO_2 (b) CO
(c) O_2 (d) NH_3

15. When a man inhales air containing normal concentration of O_2 as well as CO he suffers from suffocation because
[AIIMS 1993; BVP 2003]
(a) CO reacts with O_2 reducing its percentage in air
(b) Haemoglobin combines with CO instead of O_2 and the product cannot dissociate
(c) CO affects diaphragm and intercostal muscles
(d) CO affects the nerve of the lungs

16. Which two of the following changes ($A-B$) usually tend to occur in the plain dwellers when they move to high altitudes (3500 m or more)
(A) Increase in red blood cell size
(B) Increase in red blood cell production
(C) Increased breathing rate
(D) Increase in thrombocyte count
Changes occurring are **[CBSE PMT (Pre.) 2010]**
(a) (A) and (B) (b) (B) and (C)
(c) (C) and (D) (d) (A) and (D)

17. If a person breathes with maximal effort but with his nose and mouth closed, the alveolar pressure can be decreased to as low as
(a) −80 *mm Hg* (b) +10 *mm Hg*
(c) −180 *mm Hg* (d) −250 *mm Hg*

18. Rate of respiration is directly proportional to **[CPMT 1993]**
(a) Concentration of oxygen in blood
(b) Concentration of carbon dioxide in blood
(c) Oxygen in trachea
(d) Diaphragm expansion

19. If a man from sea coast goes to Everest peak then
[CPMT 1996; MP PMT 2002]
(a) His breathing and heart beat will increase
(b) His breathing and heart beat will decrease
(c) His respiratory rate will decrease
(d) His heart beat will decrease

20. Exposure to carbon monoxide (from coal gas) is extremely dangerous and can kill a patient because
[NCERT; KCET 1996]
(a) The compound carboxyhaemoglobin (*COHb*) it forms with heamoglobin can gradually clot the blood resulting in circulatory failure
(b) *COHb* reduces the ability of blood for transport oxygen by ruputring a vast majority of erythrocytes
(c) *COHb* greatly modifies the structure of haemoglobin, thus making it lose its affinity for oxygen
(d) None of the above

21. Blood does not transport oxygen in **[CPMT 1992]**
(a) Cockroach (b) Earthworm
(c) Frog's tadpole (d) Mammalian foetus

22. Forced deep breathing for a few minutes by a person sitting at rest may be followed by a temporary cessation of breathing. This is due to
(a) Too much O_2 in the blood
(b) Too much CO_2 in the blood
(c) Very little CO_2 in the blood
(d) Both too much O_2 and very little CO_2 in the blood

23. Hamburger phenomenon is also known as
[CMC Vellore 1993; AIIMS 1993; BHU 2001, 08; JIPMER 2002; MP PMT 2007, 09, 10]
(a) Hydrogen shift mechanism
(b) Chloride shift mechanism
(c) Carbonic acid shift mechanism
(d) Sodium–potassium pump

24. In an accident, a man dies immediately although their was no injury to brain, kidney, stomach and heart, The probable cause of death may be
(a) Coagulation of RBC
(b) Digestion stopped
(c) Diaphragm got punctured
(d) Larynx got punctured

25. Buccopharyngeal respiration in frog **[MP PMT 2000]**
(a) Is increased when nostrils are closed
(b) Stops when there is pulmonary respiration
(c) Is increased when it is catching fly
(d) Stops when mouth is opened

26. Name the chronic respiratory disorder caused mainly by cigarette smoking **[NEET (Phase-I) 2016]**
(a) Emphysema (b) Asthma
(c) Respiratory acidosis (d) Respiratory alkalosis

27. Asthma may be attributed to **[NEET (Phase-I) 2016]**
(a) Bacterial infection of the lungs
(b) Allergic reaction of the mast cells in the lungs
(c) Inflammation of the trachea
(d) Accumulation of fluid in the lungs

28. Which of the following statement(s) is/are correct **[WB JEE 2016]**
(a) Silicosis is the result of exposure to silica that causes permanent lung damage and death
(b) Transportation of gases and digested food materials in the body of higher animals causes muscle weakness and fatigue
(c) ADH is a neurohypophysial hormone that regulates body water
(d) Myasthenia gravis is a neuromuscular disease that is mediated by circulatory system

A R Assertion & Reason

Read the assertion and reason carefully to mark the correct option out of the options given below :
(a) If both the assertion and the reason are true and the reason is a correct explanation of the assertion
(b) If both the assertion and reason are true but the reason is not a correct explanation of the assertion
(c) If the assertion is true but the reason is false
(d) If both the assertion and reason are false
(e) If the assertion is false but reason is true

1. Assertion : Aerobic animals are not truely aerobic.
Reason : They produce lactic acid anaerobically.

2. Assertion : Coughing and sneezing are necessary.
Reason : Coughing and sneezing are reflex actions.

3. Assertion : Most fish when out of water, die of suffocation.
Reason : Atmospheric air contains far less oxygen content than the dissolved oxygen in water.

4. Assertion : Symptoms of emphysema develops when a person living on plains ascends and stays on a mountain.
Reason : Air pressure and partial pressure of oxygen falls with the rise in altitude.

5. Assertion : If there is no air in trachea, it will collapse.
Reason : Trachea is having the cartilagenous ring. **[AIIMS 1999]**

6. Assertion : Inspiration occurs due to muscular relaxation.
Reason : During inspiration, the diaphragm and external intercostal muscle contract simultaneously. **[AIIMS 1995]**

7. Assertion : Severe Acute Respiratory Syndrome (SARS) originated in China.
Reason : China is the most populated country of the world. **[AIIMS 2003]**

8. Assertion : Blood of insects is colourless.
Reason : The blood of insect does not play any role in transport of oxygen. **[AIIMS 1994]**

9. Assertion : Gill-lamellae in aquatic animals help in exchange of gases.
Reason : Each gill lamella carries many blood capillaries.

10. Assertion : In mammals, complex respiratory system has developed.
Reason : Mammalian skin is impermeable to gases.

11. Assertion : Insects develop a complex system of air tubes called trachea for respiratory purpose.
Reason : Exchange through body surface is not possible in insects.

12. Assertion : Aerobic respiration involves the exchange of respiratory gases twice.
Reason : Exchange occurs from lung to heart and then heart to lung.

13. Assertion : Carbonic anhydrase is present in the erythrocytes.
Reason : In erythrocytes the carbon dioxide combine with water and is transported. **[Kerala PMT 2006]**

Answers

Respiratory organs

1	d	2	a	3	d	4	d	5	d
6	d	7	c	8	d	9	a	10	b
11	a	12	d	13	d	14	a	15	c
16	d	17	a	18	d	19	d	20	d
21	a	22	d	23	c	24	b	25	c
26	d	27	c	28	a	29	c	30	d
31	a	32	b	33	d				

Pulmonary volumes and capacities

1	b	2	d	3	b	4	b	5	c
6	d	7	b	8	c	9	a	10	b
11	a	12	d	13	a	14	b	15	c
16	d	17	a	18	a	19	d	20	d
21	a								

Process of respiration

1	a	2	a	3	b	4	c	5	a
6	c	7	d	8	c	9	b	10	c
11	c	12	b	13	d	14	e	15	b
16	b	17	c	18	e	19	b	20	a
21	c	22	d	23	b	24	d	25	a
26	b	27	c	28	a	29	b	30	c
31	c	32	a	33	a	34	a	35	a
36	b	37	c	38	b	39	d	40	d
41	e	42	b	43	c	44	c	45	a
46	d	47	b	48	b	49	d	50	b
51	d	52	a	53	c	54	b	55	c
56	a	57	c	58	a	59	d	60	c
61	a	62	c	63	a	64	b	65	c
66	c								

Control of breathing

1	a	2	c	3	c	4	c	5	b
6	a	7	a	8	a	9	b	10	b
11	c	12	b						

Important concepts of respiration

1	c	2	a	3	d	4	c	5	d
6	b								

Disorders of respiration system

1	a	2	c	3	c	4	c	5	c
6	c	7	d	8	d	9	a	10	d
11	d	12	c	13	b	14	d	15	a
16	d	17	b						

NCERT Exemplar Questions

1	d	2	d	3	d	4	b	5	a
6	d	7	d	8	b	9	b	10	b
11	b	12	b	13	b				

Critical Thinking Questions

1	d	2	b	3	d	4	d	5	d
6	e	7	d	8	c	9	b	10	a
11	a	12	a	13	b	14	b	15	b
16	b	17	a	18	b	19	a	20	c
21	a	22	d	23	b	24	c	25	d
26	a	27	b	28	acd				

Assertion and Reason

1	a	2	b	3	c	4	e	5	e
6	e	7	b	8	b	9	a	10	b
11	a	12	c	13	a				

Answers and Solutions

Respiratory organs

3. (d) Haemolymph is found in insect blood which is colourless.

7. (c) In forced expiration internal intercostal muscles and some abdominal muscles contract to reduce the volume of thorax.

10. (b) Inside the larynx there are vocal cords. These are two pairs of fold of mucous membrane that extend into the lumen of the larynx from the sides.

12. (d) The pharynx provides passage to both air and food.

14. (a) In man, the left lungs has two lobes, superior lobe and inferior lobe, the right lungs has three lobes superior lobe, middle lobe and inferior lobe.

18. (d) Earthworm has a closed circulatory system. *Hb* dissolved in plasma of blood acts as a respiratory pigment, transporting O_2 to the body tissues.

23. (c) In rabbit, the left lung is divided into two lobes, left anterior and left posterior whereas the right lung has four lobes, anterior azygous, right anterior right posterior and posterior azygous.

24. (b) Each lung is enclosed in two membranes called pleurae. The outer covering is adhered to chest wall and diaphragm and is called parietal pleura. The inner covering membrane, which closely covers the lung, is called visceral pleura.

27. (c) Haemocyanin is copper containing pigment. It is respiratory pigment of Prawn. Haemocyanin becomes blue when oxygenated and colourless during deoxygenation.

30. (d) It serves to close the glottis during deglutition thereby preventing entry of food into respiratory tract.

31. (a) Diaphragm has no role in the respiration in frog but in mammals it increase the surface area for respiration.

33. (d) Presence of diaphragm is mammalian character, which is dome-shaped partition that separates the thoracic and abdominal cavities.

Pulmonary volumes and capacities

5. (c) Vital capacity of lungs to expire maximum volume of air after a deep inspiration. The largest quantity of air that can be expired after a maximal inspiratory. Vital capacity is equal the sum of the tidal complemental and supplemental air (500 + 3100 + 1200 = 4800 *ml*).

9. (a) The volume of air inspired and expired with each normal breath is tidal volume, which is approximately 500 ml.

12. (d) The residual volume is that part of the air in the lung which cannot be exhaled; it represents the remaining volume of lung when forced exhalation of the lung has occurred.

Process of respiration

1. (a) More active tissue has much lower PO_2. Therefore much more oxygen is released from oxyhaemoglobin in the active tissue.

3. (b) The gaseous exchange is the simple diffusion of oxygen from alveolar air into the blood and diffusion of CO_2 from blood to alveolar air.

5. (a) Oxygen tends to displace CO_2 so that the curve shifts more to the right.

11. (c) This pump is connected through a tube to an external machine for inflating or deflating it with helium.

13. (d) Nearly 20-25 percent of CO_2 is transported by RBCs, whereas, 70 percent of it is carried as bicarbonates. About 7 percent of CO_2 is carried as dissolved state in plasma.

25. (a) Under a given oxygen concentration in blood, dissociation of oxyhaemoglobin will increase if *p*H of blood falls.

28. (a) O_2 dissociation curve for haemoglobin is sigmoid in shape.

29. (b) During expiration diaphragm relaxes and becomes dome–shaped thereby reducing intrathoracic volume to pass out the air from body.

31. (c) During pulmonary respiration mouth remains closed all the time whereas nostrils are opened only when air is taken in or passed out *i.e.* during first stroke of inspiration and second stroke of expiration respectively.

32. (a) In anaerobic respiration pyruvate undergoes two types of incomplete reduction. In one case it results in the production of ethyl alcohol (Yeast) and in other it produces lactic acid (muscles).

38. (b) Billirubin is an orange pigment that is one of the end product of haemoglobin breakdown in the hepatocyte and is excreted as a waste material in bile.

39. (d) In the form of H_2CO_3 dissolved in plasma and $NaCO_3$ and $KHCO_3$ as bicarbonates.

43. (c) A is the alveolar cavity which is the main site of exchange of respiratory gases.

45. (a) Rise in CO_2 concentration is detected by chemosensitive area activates inspiratory centre in Medulla oblongata, which lead to urge of breathing. Role of O_2 concentration is non significant.

47. (b) During normal breathing the respiratory movement in 25 years old is about 16/*min*.

48. (b) To maintain electrostatic neutrality of plasma, many chloride ions diffuse from plasma into RBCs and bicarbonate ions pass out. The chloride content of RBCs increases when oxygenated blood becomes deoxygenated. This termed as chloride shift or Hamburger shift.

50. (b) Sternohyal and petrohyal helps in respiration of frog. Contraction of sternohyal muscle during breathing in frog lowers floor of oral cavity. While contraction of petrohyal muscle during breathing in frog raises the floor of buccal cavity.

53. (c) 7% of CO_2 is transported in dissolved form in the plasma, 23% as carbaminohaemoglobin and 70% in the form of bicarbonates.

54. (b) Our tissues are able to utilise only 25% of O_2 carried by artetrial blood. Our venous blood is still 75% saturated with O_2. This O_2 acts as a reserve during muscular exercise.

57. (c) Respiration is the process of oxidation by which food material are oxidized and produce CO_2 and water as waste product.

59. (d) Surfactant is a lipoprotein secreted by surfactant secreting cells, which form part of alveolar epithelium. This tends to reduce the surface tension of fluid lining the alveoli and thus facilitates lung expansion and also maintains the stable size of the alveoli.

60. (c) In the form of phosphate bond energy.

63. (a) During inspiration the diaphragm and external intercostal contract simultaneously. This moves the lateral thoracic walls outward and upward.

66. (c) PO_2 in Alveoli is 104, while in oxygenated blood, it is 95.

Control of breathing

1. (a) Tidal volume is the volume of air breathed in and out during normal respiration and is equal to about 500 *ml* or 0.5*l*

3. (c) Tidal volume is the volume of air inspired or expired with each breath. This is about 500 *ml* in an adult person.

6. (a) Because the respiratory centres are located in the medulla oblongata and pons varoli in the hind brain.

8. (a) Breathing is controlled by pneumotaxic and apneustic centres in pons varoli and expiratory and inspiratory centres in medulla oblongata.

10. (b) A chemosensitive area located close to the respiratory centre in medulla is highly sensitive to changes in PCO_2 or *pH* of the blood.

Important concepts of respiration

3. (d) Hemoglobin, an iron containing red pigment is responsible for transport of O_2 and CO_2 in human blood.

4. (c) The affinity of haemoglobin for CO is approximately 210 times greater than O_2.

6. (b) The oxygenated blood from two lungs is collected by right and left pulmmonary veins, which unite to form a common pulmonary vein (Pulmocutaneous vein) which open directly into the left auricle, on the dorsal side.

Disorders of respiration system

1. (a) Rate of O_2 supply by lungs into muscles falls down during active work or in exercise. Muscles accumulate lactic acid and slowly breathing becomes hard so as to increase O_2 intake in lungs. This stage is called oxygen debt.

2. (c) Because plants release pollen grain a fix time and it is generally March-April or Aug. – Sep.

8. (d) Cyanosis is blueness of skin and occurs due to large amount of deoxygenated haemoglobin in cutaneous vessels.

12. (c) Oxygen toxicity develops when pure oxygen is breathed in for a prolonged period. This is formed due to progressive failure of ventilation of lungs.

13. (b) Diabetic patient shows low R.Q. due to the increased dissimilation of fats and decreased dissimilation of carbohydrates.

16. (d) Emphysema is the respiratory disorder in which the septa between the alveoli are destroyed and much of the elastic tissue of the lungs is replaced by connective tissue. It is generally caused by a long term irritation. Air pollution, occupational exposure to industrial dust and cigarette smoke are the most common irritants.

Critical Thinking Question

1. (d) Some snakes have only one bronchus and the right lung.

2. (b) In mammalian lungs each alveolar duct ends in a passage, called atrium, which leads into a number of rounded alveolar sacs. Each alveolar sac is studded with a large number of air sacs or alveoli. Alveoli are the sites of respiration.

3. (d) Syrinx is a sound producing organ in birds.

4. (d) The respiratory centres that control the breathing mechanism are present in medulla oblongata. These respiratory centres are expiratory centre and inspiratory centre.

5. (d) The number of alveoli in human lungs has been estimated to be approximately 750 million, exposing a surface area of nearly $100\ m^2$.

7. (d) The nerve impulse ordered by respiratory centre passes through vagus nerve to the intercostal muscles and diaphragm and regulates respiration. The respiratory centres are scattered in brain stem and are constantly giving off rhythmically stimuli to the respiratory muscles in virtue of their inherent rhythm causing inspiration and expiration.

9. (b) Every 100 ml of blood receives an average 3.7 ml of CO_2 from tissues.

15. (b) Carbon monoxide has 210 times more affinity with haemoglobin as compared to O_2 and forms a stable compound.

18. (b) Due to direct chemical control on respiratory centres, CO_2 stimulates respiratory centres in CNS.

19. (a) At high altitude, PO_2 of alveolar air falls because of low O_2 tension of tissues. So, O_2 is absorbed very quickly from alveoli, thus, increasing breathing rate. Heart beat also increases to supply required amount of O_2 to tissues.

20. (c) $COHb$ is a stable compound formed by the combination of carbon monoxide and haemoglobin. It has more affinity than oxygen.

21. (a) Due to absence of respiratory pigment.

22. (d) Deep breathing rises the O_2 level of the blood. By excess formation of oxyhaemoglobin the acidity of blood increases. To control it, more of free CO_2 changes into bicarbonates and the free CO_2 level in the blood decreases. So due to lack of stimulant for inspiratory centre cessation of breathing takes place, after some time O_2 is consumed by the tissues and rise in CO_2 stimulates breathing again.

23. (b) To maintain electrostatic neutrality of plasma, many chloride ions diffuse from plasma into RBCs and bicarbonate ions pass out. The chloride content of RBCs increase when oxygenated blood become deoxygenated. This is termed as chloride shift or Hamburger phenomenon.

25. (d) This process occurs through nares and mouth and gullet are kept closed during the process.

28. (acd) Silicosis is an occupational lung disease that causes progressive respiratory failure and death. ADH is synthesized from hypothalamic nuclei and are responsible for water absorption by nephron. Myasthenia gravis is an autoimmune disorder mediated by antibodies.

Assertion and Reason

1. (a) In most animals, tissue oxidation are carried out by aerobic respiration. But sometimes in aerobically respiring animals, anaerobic metabolism take place in certain tissues like skeletal muscles which do not immediately get as much oxygen as in necessary for their acid anaeorbically from glucose during vigorous movements.

2. (b) Coughing and sneezing are necessary to take place because these reactions serve to keep the air passages free from foreign matter. Coughing is a reflex action under nervous control. The minute receptors found in the wall of trachea, bronchi, bronchioles and alveoli are highly sensitive to foreign matter (smoke, dust etc.) Like coughing, sneezing is also a reflex action triggered because of irritation to nasal passages. In this, sensory impulses travel from nasal passages to the medulla through trigeminal nerves. The reaction involves the same series of events as in cough reflex, but the air explodes out both through nose and mouth, expelling the foreign matter from nasal passages.

3. (c) Although atmospheric air contains far more oxygen content than the water (air contain 21% oxygen and water contains 0.5-0.9% oxygen by volume depending on the temperature), still most fish when out of water die of suffocation due to lack of oxygen. When fish is taken out of water the gills stick together thereby reducing the surface area. Reduced surface area lowers gas exchange so death ensues.

4. (e) When a person living on plains ascend and stays on a mountain above 8000 feet from the sea level, he develops symptoms of mountain sickness which includes breathlessness, headache, dizziness, irritability, nausea, vomiting, mental fatigue and a bluish tinge on the skin, nails and lips.

We know that with the rise in altitude, the barometric pressure and consequently the partial pressure of oxygen falls in the atmospheric air. This lowers the alveolar partial pressure of oxygen which causes reduction in the diffusion of oxygen from the alveolar air to the blood. So oxygenation of blood is decreased progressively, which produces the symptoms of mountain sickness, Emphysema.

5. (e) There is no air in trachea, it does not collapse due to the presence of C-shaped narrow cartilaginous ring or discs.

6. (e) Inspiration is the result of muscular contraction. The diaphragm and external intercostal muscle contracts simultaneously. The lateral thoracic wall moves outward and upward.

7. (b) The world health organization (WHO) reported China as the origin place of SARS. Several other countries have reported SARS cases after travel to China and its nearby areas/countries in Asia or close contact with a person affected with SARS. Microbiologists of Hongkong Central University initially detected a virus metapneumovirus and identified as corona virus causative agent of SARS. It is very known fact that the China is the most populated country. This fact cannot be correlated with SARS

8. (b) Blood is colorless in insects. Insects have tracheal respiration. It is carried on by an extensive system of inter-communicating tubes called trachea.

9. (a) Gills are the main respiratory organs of aquatic animals. Each gill bears rows of comb-like, soft, thin gill-filament, each gill-filament bears many flat, parallel membrane-like gill-lamellae. Each gill lamella carries many blood capillaries. Water taken through the mouth, is made to flow from the pharynx in a single direction between the gill lamella. Blood flows in the capillaries of gill-lamella in a direction opposite to the flow of water over the lamellar surfaces. This greatly helps in the gaseous exchange across the lamellar membrane between the capillary blood and the flowing water.

10. (b) Mammalian skin in impermeable so that water loss through it is minimized. But mammals need far more oxygen to maintain their high metabolic rates than lower animals; so they need a more extensive respiratory surface. Thus a complex respiratory system has evolved in mammals to meet this need. The mammalian respiratory system consists of the nasal cavity, nasopharynx, larynx, trachea, bronchi, bronchiole and lungs.

11. (a) As the integument of insect is thick and impermeable to minimize lose of body water, they can not carryout gas exchange through their body surface. To overcome this difficulty they have developed a complex system of air tubes called trachea to reach the air directly near the tissue cells. Each trachea communicates with the exterior through openings in the body wall.

12. (c) Aerobic respiration involves the exchange of respiratory gases at two places in multicellular animals-one between the body surface and surrounding medium, the other between the individual cells and the extra cellular fluid. Lungs are involved in the first step of exchange, but not the heart.

13. (a)