# Gaseous Exchange

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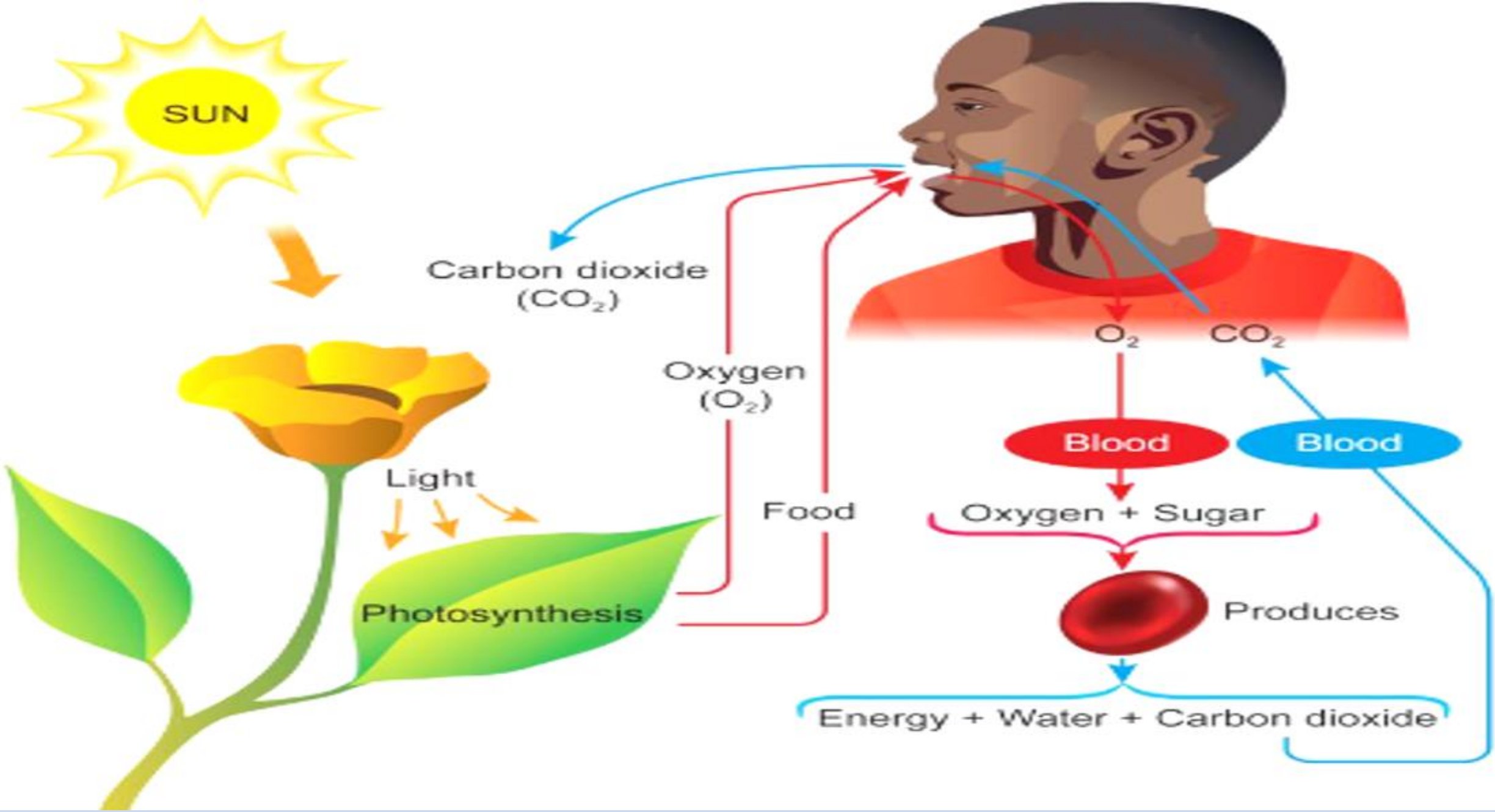

SUN
Carbon dioxide
($CO_2$)
Oxygen
($O_2$)
Light
Photosynthesis
Food
$O_2$
$CO_2$
Blood
Blood
Oxygen + Sugar
Produces
Energy + Water + Carbon dioxide

## *Definition:*

This is the process by which respiratory gases are exchanged between **external media** and the **body cells**. It is also known as ***external respiration***

## Need for Gaseous Exchange

- ✓ Enables organisms to get oxygen for respiration.
- ✓ To get rid of waste products of respiration like carbon dioxide
- ✓ Enables green plants to obtain carbon dioxide for photosynthesis

# Note:

the movement of gases to and from respiratory surface is called ***ventilation (breathing).***

**Breathing** is an ***active process*** involving movement of **air in** and **out** of the body whereas

**Gaseous exchange** is a ***passive process*** involving passage of air through respiratory surfaces/gaseous exchange surfaces.

**Respiratory surfaces** are sites where gaseous exchange takes place in the body of the organism.

# *Respiratory surfaces and corresponding respiratory organs*

| Animal | Respiratory organ | Respiratory surface |
|---|---|---|
| Amphibians | Lungs | Alveolus |
| | Skin | Skin surface |
| | Buccal cavity | Buccal cavity epithelium |
| Fish | Gills | Gill filaments |
| Insects | Tracheal system | Tracheoles |
| Tadpoles | Gills | Alveolus |
| Mammals | Lungs | Gill filaments |

# ***NOTE:***

Across all respiratory surfaces, gaseous exchange occurs by ***diffusion***, thus,

factors that affect the **rate of diffusion** are the same factors that affect gaseous exchange as discussed in transport.

# *Characteristics / adaptations of good respiratory surfaces*

*i) Have **a large surface area to volume ratio** to enable rapid diffusion of gases. This is achieved **by folding or branching of structures** to form alveoli in lungs, gill filaments in the gills and tracheoles in insects.*

***ii) Kept moist** to dissolve gases for easy diffusion.*

***iii) Thin walled** to reduce on the distance over which diffusion has to take place.*

*iv) Have **many blood capillaries** to transport oxygen and carbon dioxide gases to and from the respiring tissues to maintain a high concentration gradient.*

***v) Well ventilated** to supply oxygen to the respiratory organ from the atmosphere and remove carbon dioxide from the respiratory organ to the atmosphere. This also maintains a high concentration gradient.*

# ***Effect of Size and Surface Area***

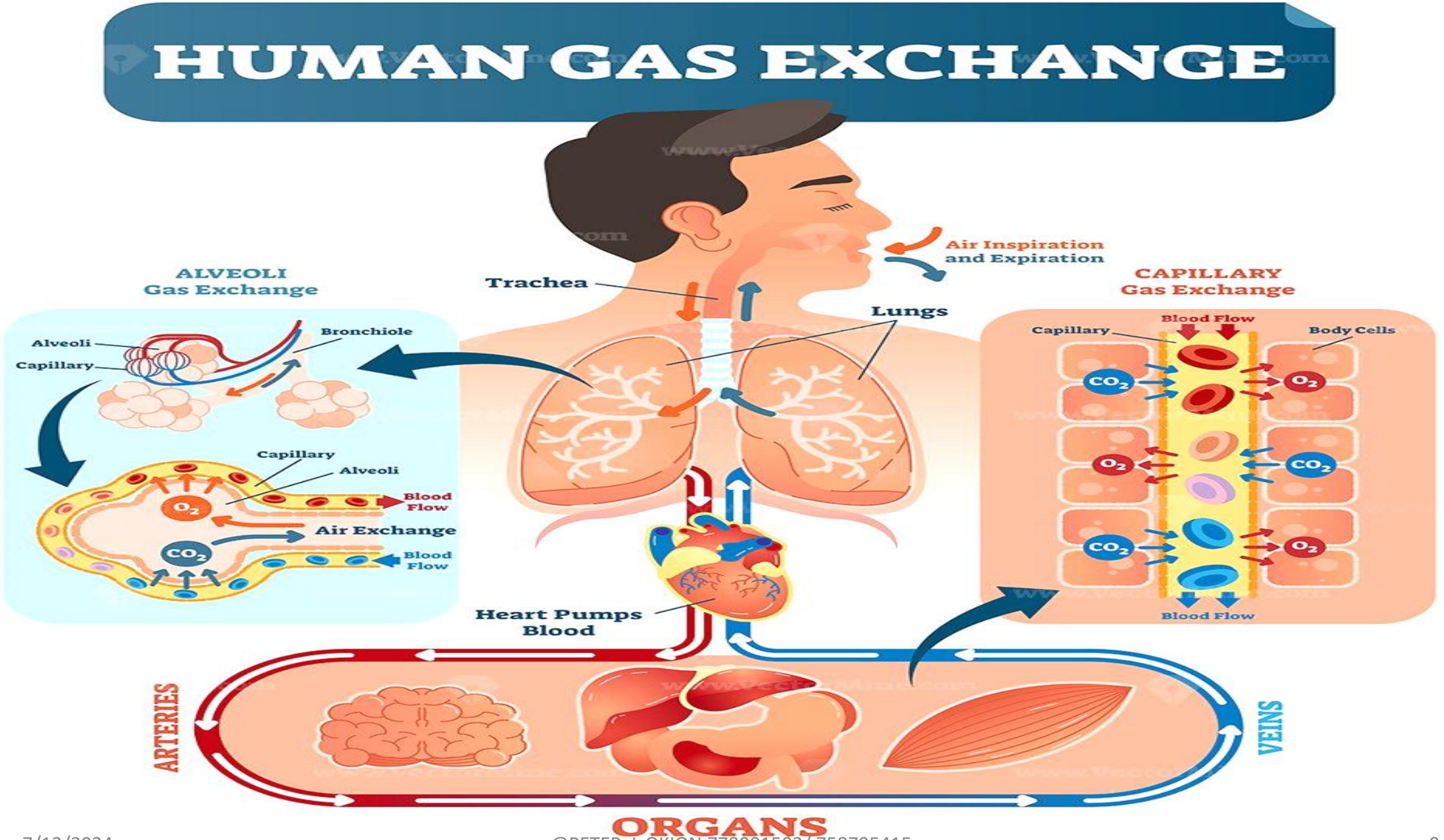
1. Small organisms like ***amoeba, paramecium, hydra and jellyfish*** have a ***large surface area to volume ratio***. In such organisms, gaseous exchange takes place over the whole-body surface. Because of their small body volume, **diffusion** alone is **enough** to transport oxygen and carbon dioxide into, around and out of their bodies.

2. Larger organisms on the other hand have a ***smaller surface area to volume ratio.***

This reduces the rate of diffusion and **diffusion alone cannot meet the respiratory demands** of their large bodies. They also have a large diffusion distance because they have very ***many layers of cells***.

Due to this, large organisms have developed mechanisms, which reduce on the diffusion distance and increase the surface area to volume ratio. **For instance**;

**Mammals** have developed a **blood circulatory system** which transports respiratory gases through highly branched blood vessels to all cells of the body


HUMAN GAS EXCHANGE
Air Inspiration and Expiration
Trachea
Lungs
ALVEOLI
Gas Exchange
Alveoli
Capillary
Bronchiole
Capillary
Alveoli
Blood Flow
Air Exchange
Blood Flow
CAPILLARY
Gas Exchange
Capillary
Blood Flow
Body Cells
Blood Flow
Heart Pumps Blood
ARTERIES
VEINS
ORGANS

The respiratory organs in man are **lungs** and the respiratory surfaces are the sac like structures called **alveoli.**

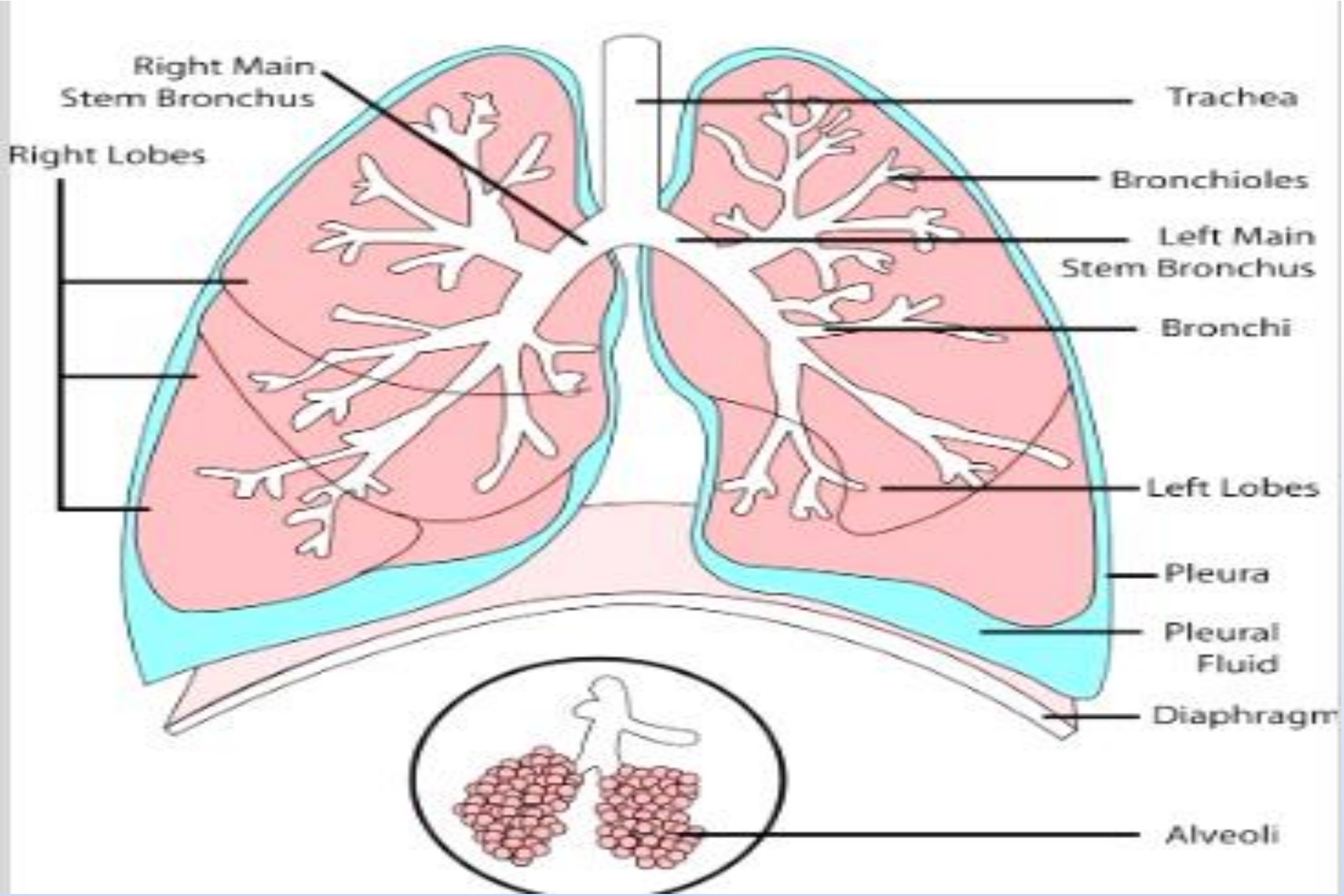
# Structure of Lungs

These are ***two spongy-like*** structures within the thoracic cavity that are protected by the ***ribs*** which are lined by the ***intercostal muscles*** (***internal and external***).

A sheet of ***muscular tissue*** separates the abdominal cavity from the thoracic cavity and this muscle is called the ***diaphragm***.

Each lung is completely surrounded by a two-layered membrane called ***pleural membrane***.

Between the two layers is the ***pleural cavity***, which contains a lubricating fluid called ***pleural fluid***.


Right Main
Stem Bronchus
Right Lobes
Trachea
Bronchioles
Left Main
Stem Bronchus
Bronchi
Left Lobes
Pleura
Pleural
Fluid
Diaphragm
Alveoli

# ***The respiratory tract (air passage)***

Air enters through the ***nostrils*** into the ***nasal cavity*** where it is warmed to body temperature.

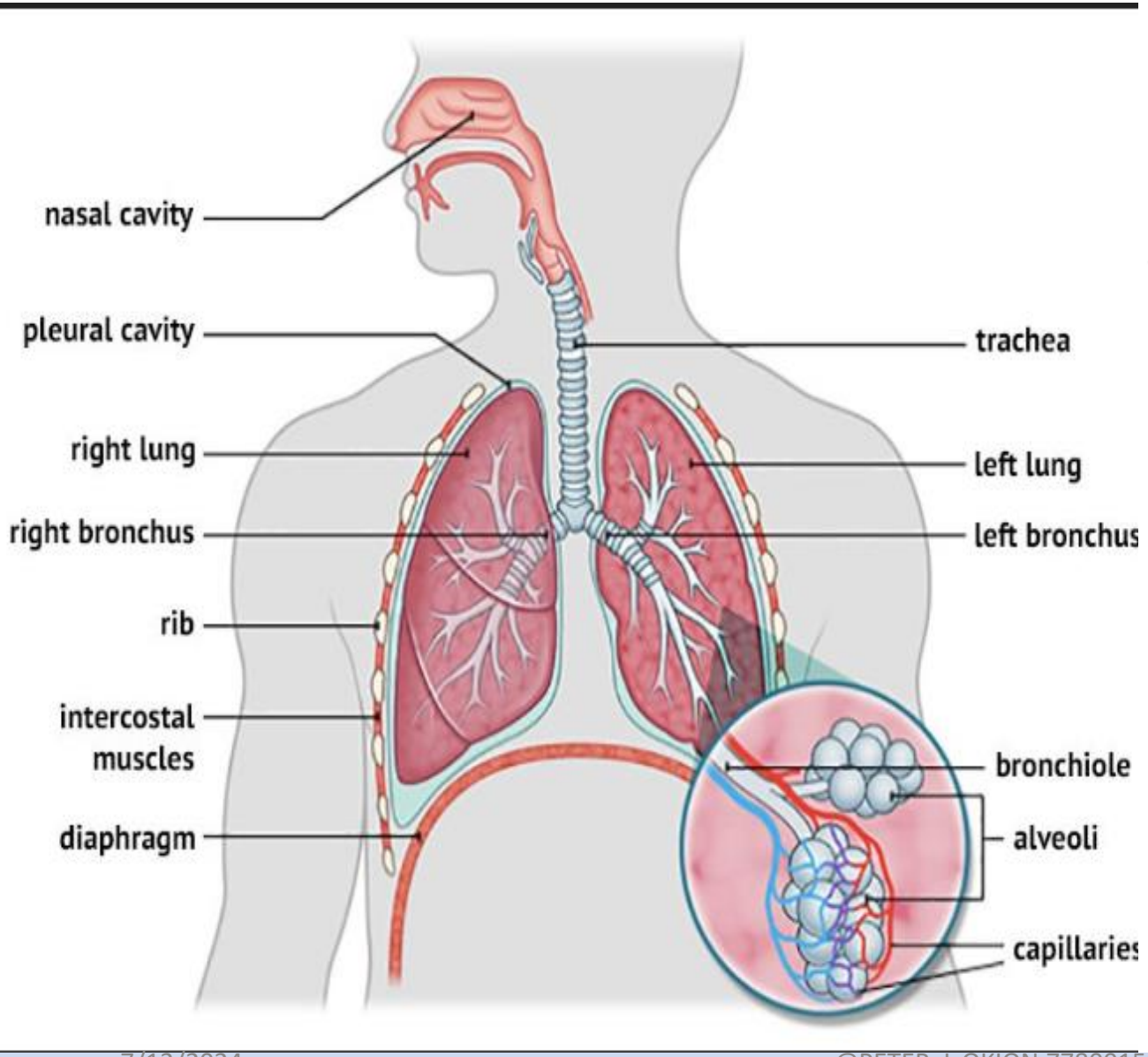
The nasal cavity is lined with **mucus secreting cells** and ***hairs***. The mucus and hairs **filter** and **trap** ***dust*** and **micro-organisms** from the air.

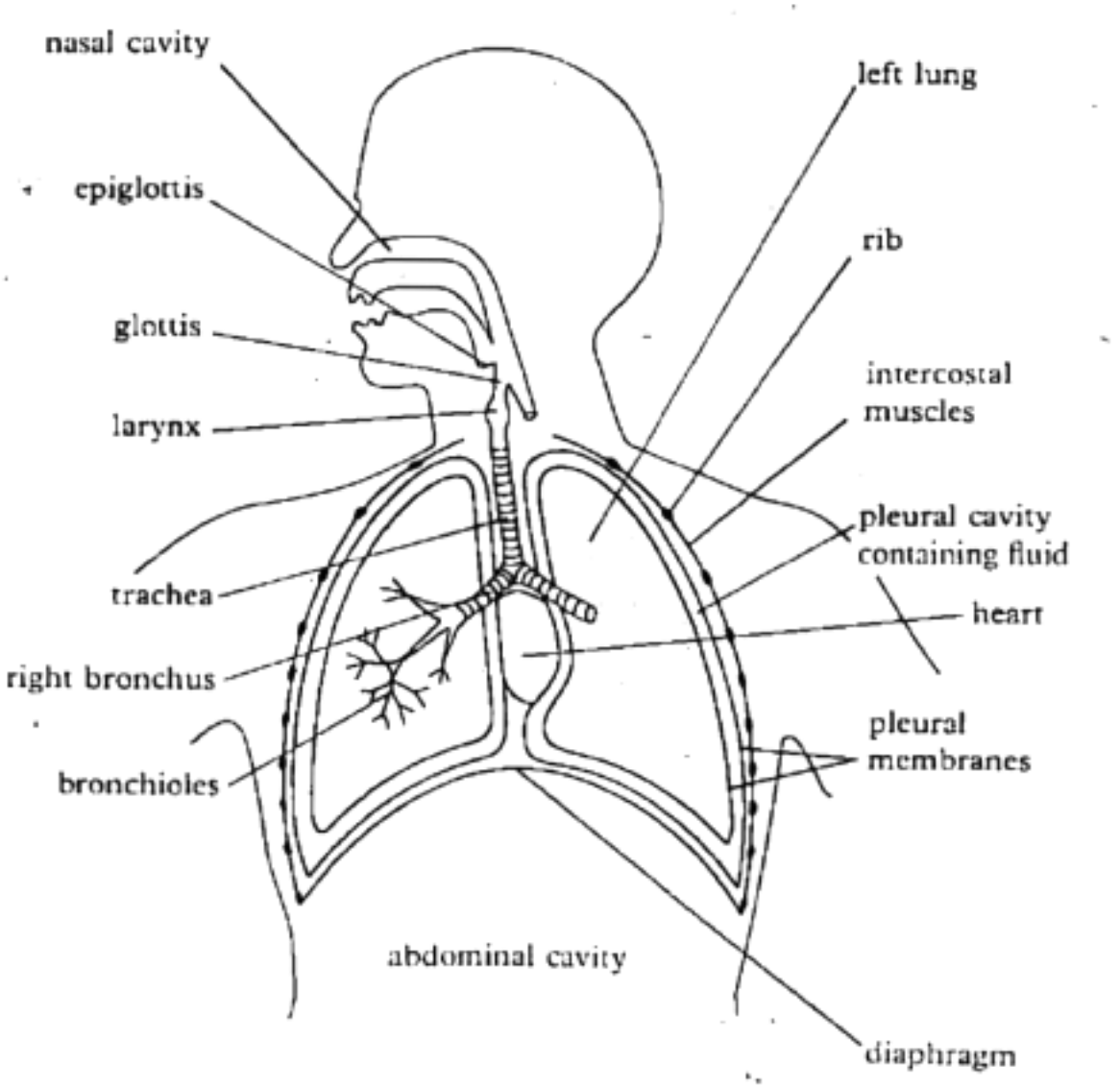
The air is then passed to the ***pharynx*** from which it goes into the ***larynx*** through a small opening called **glottis** which has a **flap** known as the **epiglottis** which closes when a person is swallowing to prevent food from entering the ***trachea***.

The air then enters the **trachea**. Choking and coughing are reflex actions which remove any liquid or solid particles which accidentally enter the trachea.

From here, air travels to the **lungs** through the **bronchus**, **bronchioles** and lastly to the **alveolus.**

# The respiratory tract system



# *Functions of Parts:*

## ***Nose***

This is a point where air enters and leaves the respiratory surface although the mouth can do the same. The walls of the nose are lined with hairs which trap dust and other foreign materials that may come along with the respiratory gases.

## ***Pharynx***

This is the back of the mouth where the nasal cavity and the mouth cavity join together. It is at the pharynx that the ***oesophagus*** and ***trachea*** meet.

## ***Larynx***

This is a cavity at the top of the trachea. It contains the ***vocal cords*** which vibrate to produce ***sound*** when air passes over them.

Near the larynx is a flap of cartilage known as the **epiglottis** which prevents dust and other foreign particles from entering the trachea during swallowing.

# Trachea

This is a tube running from the ***pharynx*** to the ***lungs***. Its walls contain ring-like cartilage which prevents the trachea from collapsing when pressure in it falls.

## *Adaptations of Trachea*

- It is hollow so readily allows gases to pass through
- It is kept open by rings of cartilage
- Secretes mucus which traps dust particles
- Has cilia which beats to move mucus and dust up to the larynx.

# Bronchi

There are ***two*** bronchi tubes branching from the trachea.

They also have rings of ***cartilage*** which keep them permanently open.

Each bronchus leads to one lung and divides to form a mass of fine tubes called the ***bronchioles***.

# ***Bronchioles***

These are tiny tubes branching form the bronchi ***without*** rings of cartilage. Bronchioles end in baglike sacks called ***alveoli***.

## ***Alveoli***

These are the ***sites*** of actual gaseous exchange in the lungs.

They are ***numerous*** and composed of thin walls.

Their membranes are completely ***moistened*** to dissolve respiratory gases.

# *Mechanism of Breathing in Man*

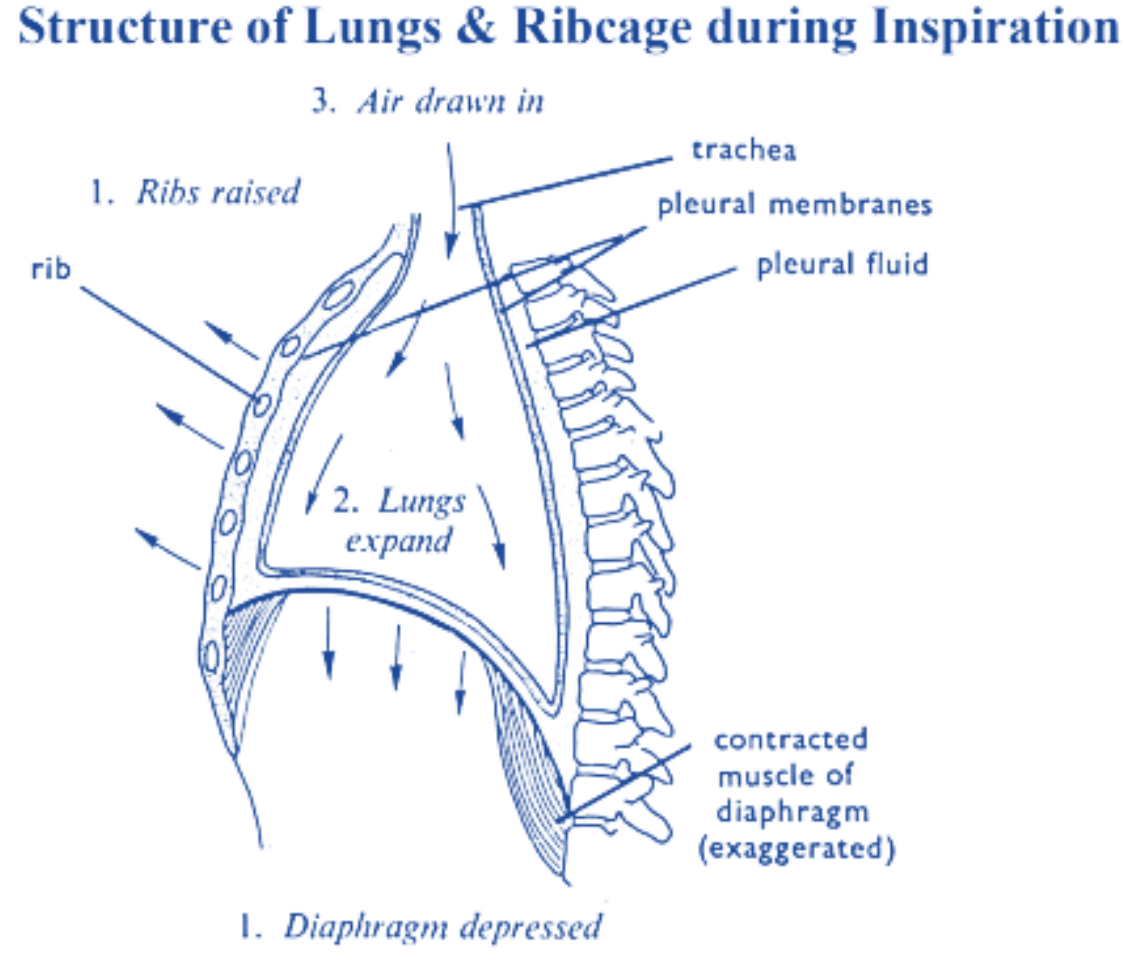
Breathing in man occurs in two phase i.e.

***a) Inspiration***

***b) Expiration***

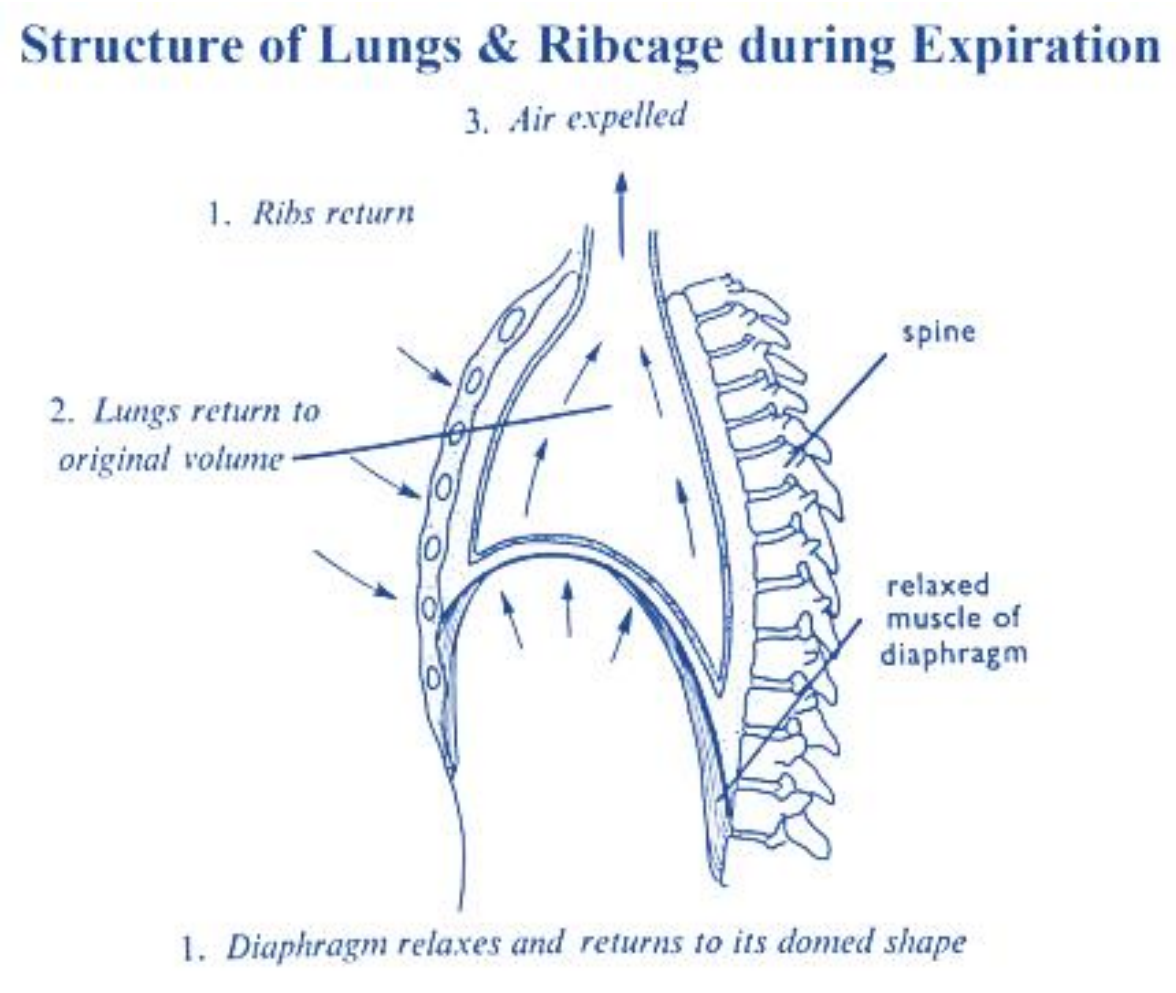
# Inspiration

1. External intercostal muscles contract. Internal intercostal muscles relax.
2. Rib cage moves upwards and outwards.
3. Diaphragm muscles contract and diaphragm flattens.
4. Volume of the thoracic cavity increases.
5. Air pressure in the lungs and thoracic cavity decreases compared to external atmospheric pressure.
6. External air is driven into the lungs due to the pressure difference between the inside and the outside.
7. Lungs inflate



# Expiration

1. External intercostal muscles relax. Internal intercostal muscles contract.
2. Rib cage moves downwards and inwards.
3. Diaphragm muscles relax and diaphragm forms a dome shape.
4. Volume of the thoracic cavity decreases
5. Air pressure in the lungs and thoracic cavity increases compared to external atmospheric pressure.
6. Air in the lungs is compressed and forced out.
7. Lungs deflate



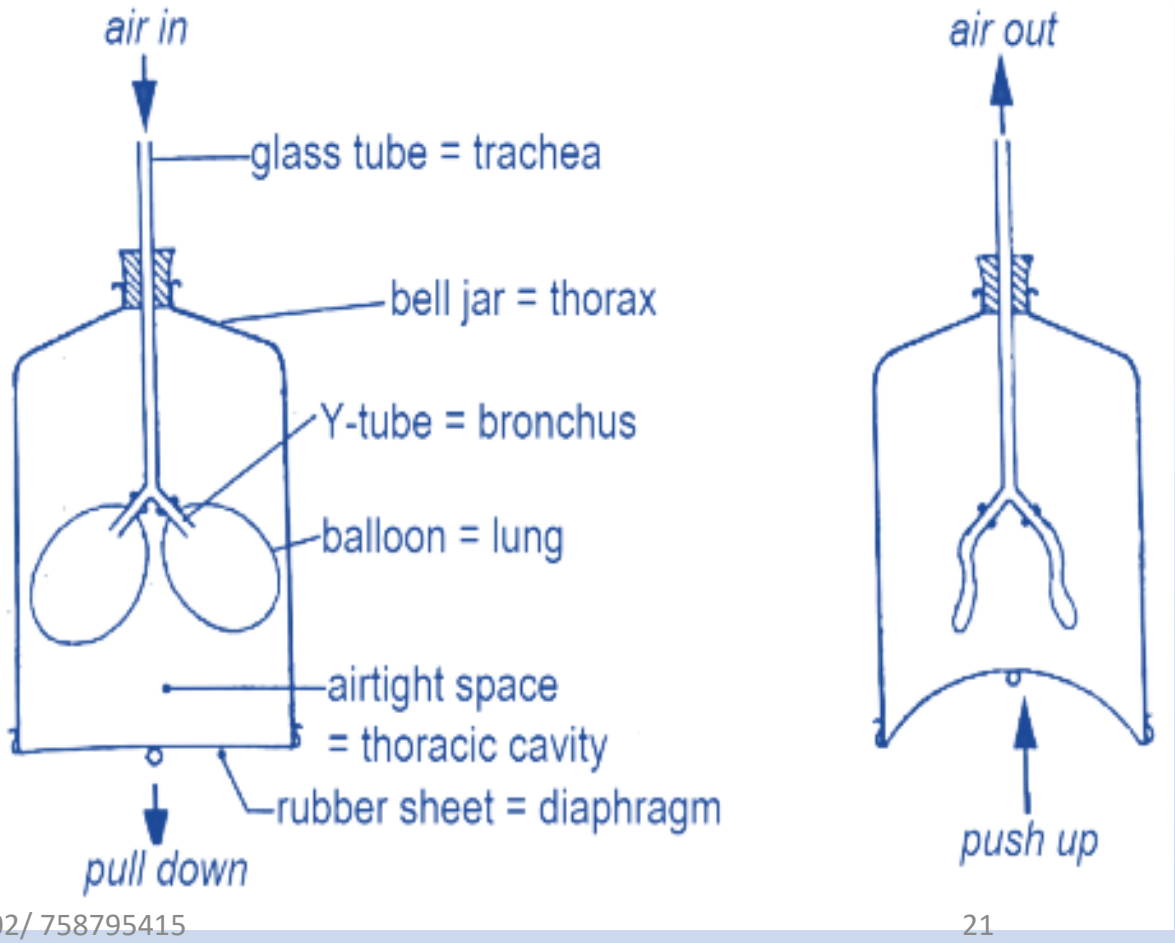
# Model to Demonstrate Gaseous Exchange in Man

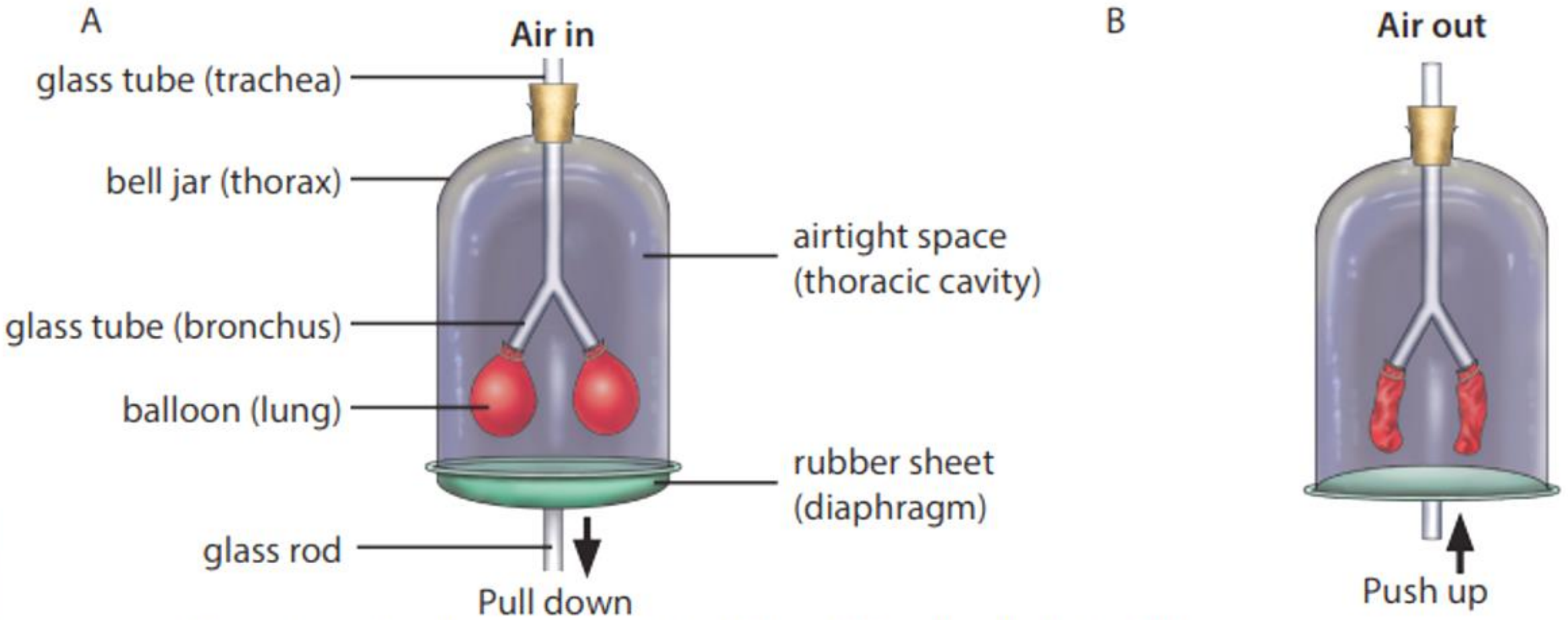
**Materials:** Glass tubing, cork, rubber tubing, Y-tube, bell jar, two balloons, rubber sheet and thread.

## Procedure:

- Set up the apparatus as shown in the figure below. Make the jar airtight by filling the gaps using petroleum jelly.
- Pull down the rubber sheet at the base of the bell jar.
- Observe what happens to the balloons.
- Then release the rubber sheet slowly and observe what happens to the balloons.
- Identify and label the parts in the set up that are similar to the breathing mechanism in a living mammal.

## Set up






Experiment to demonstrate inhalation (A), and exhalation (B)

# Observation:

1. When the thread is ***pulled***, the rubber sheet ***stretches***. This increases the volume in the bell jar and reduces the pressure. Air enters from out through the glass tube to the Y-tube and ***inflates*** the balloons.

2. When the thread is ***released***, the rubber sheet returns to its normal ***flat shape***. This reduces the volume in the bell jar and increases the pressure. Air is forced out of the balloons through the Y-tube and glass tubing. This ***deflates*** the balloons.

# Conclusion:

Pulling of the thread represents ***inspiration*** and its release represents ***expiration***.

# Components of Inhaled & Exhaled Air

| Component | Inhaled air | Exhaled air |
|---|---|---|
| Nitrogen | 79% | 79% |
| Oxygen | 21% | 17% |
| Carbon dioxide | 0.03% | 4% |
| Water vapor | Less saturated (variable) | Saturated |
| Temperature | Atmospheric temperature | Body temperature |

# Explanation:

Although **nitrogen** is exchanged within the lungs and blood plasma, it plays no part in chemical reactions of the body hence its composition **remains the same** in inspired and expired air.

Inhaled air has **more oxygen while** exhaled air has less oxygen; because it is taken up for the process of **respiration**, which produces out **CO2**.

Hence exhaled air **contains more CO2 while** inhaled air has less carbon dioxide.

However, the process of gaseous exchange in alveoli does not remove all the carbon dioxide and oxygen in air.

**Water vapor** is produced as a bi-product of many metabolic processes in the body so expired air contains saturated water vapor.

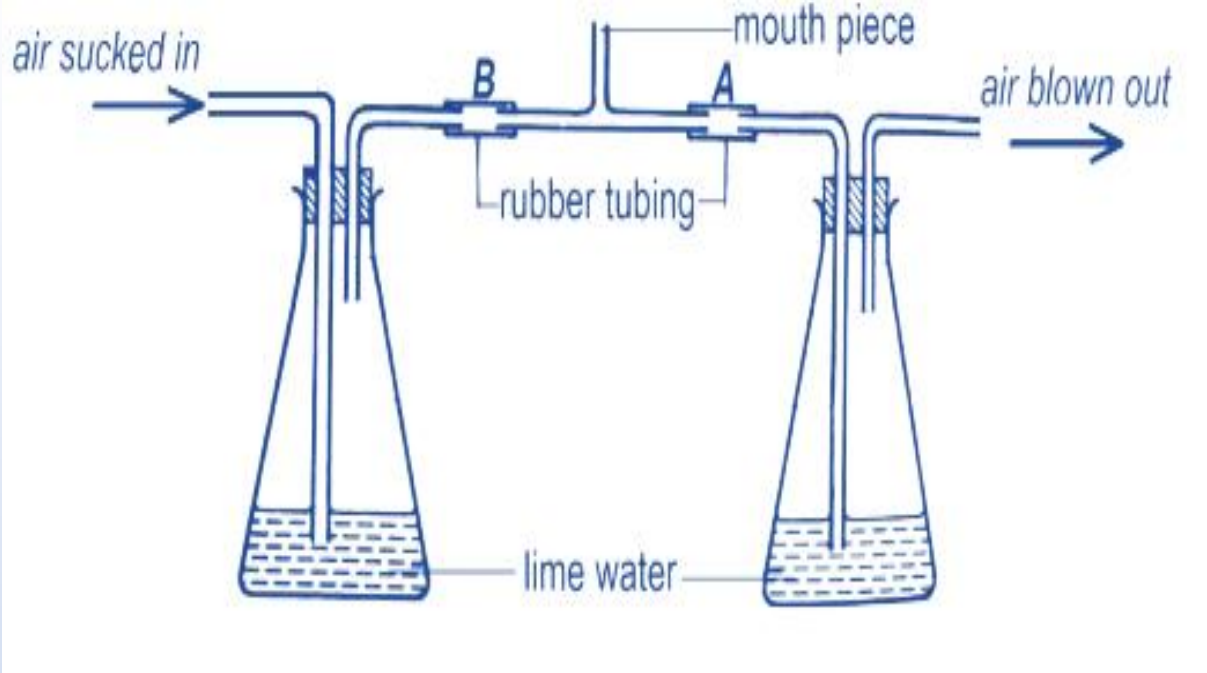
# An experiment to show that exhaled air contains carbon dioxide

**Materials:** thistle funnel, cotton wool, two conical flasks, lime water, two rubber tubings, a T-tube and three delivery tubes.

## Procedure:

- ✓• Prepare the apparatus as shown in the figure below:
- ✓•Hold tight to close rubber tubing A and breathe in through the mouthpiece, release the rubber tubing A and hold to close rubber tubing B and breathe out still through the mouthpiece.
- ✓•Repeat the procedure three times while observing the changes on the lime water.

## Set up



# Observation:

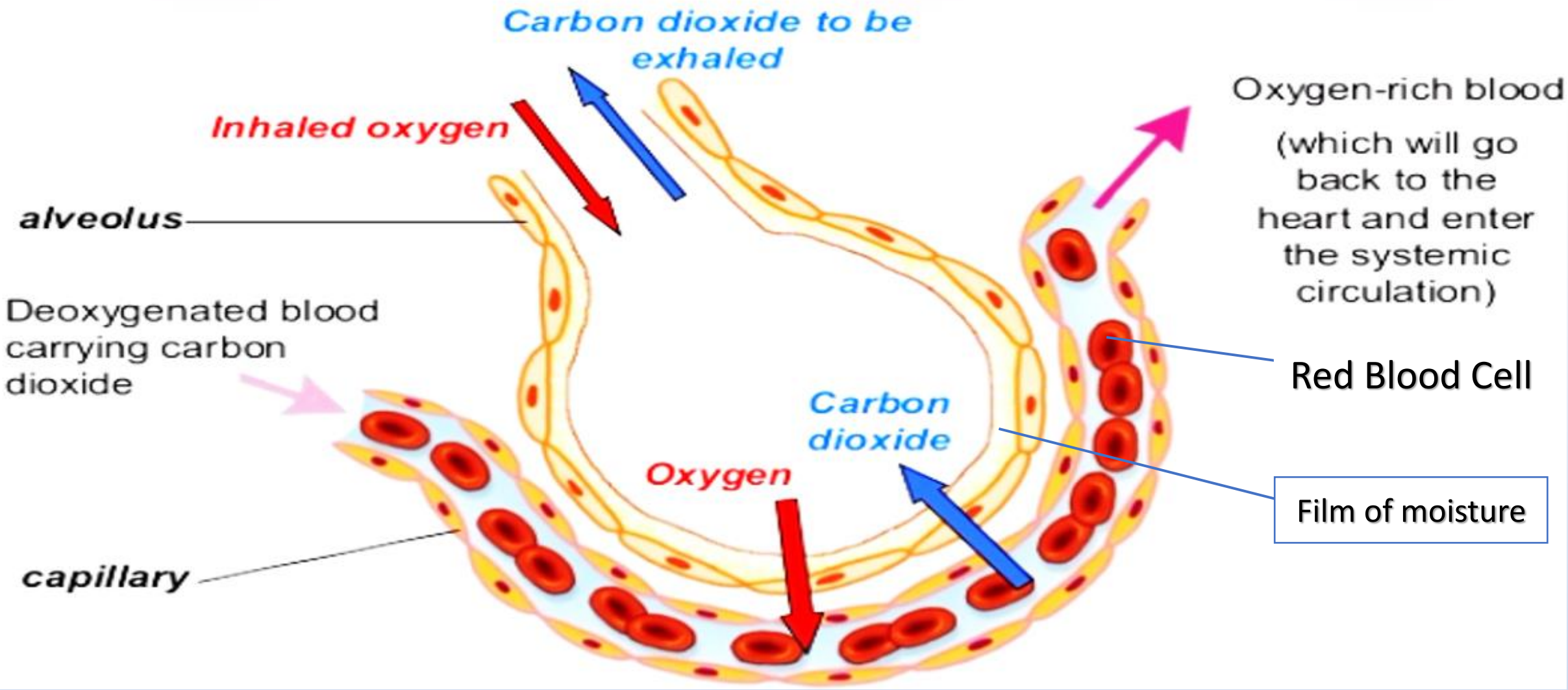
The lime water in the conical flask where air blown out passes turns **milky** whereas

The lime water in the conical flask where air sucked in passes remains **clear**.

# Conclusion:

Exhaled air contains carbon dioxide gas.

# Gaseous Exchange in the Alveolus



# description of gas exchange at the alveolus

Gas exchange between the air within the alveoli and the pulmonary capillaries occurs by **diffusion**.

Oxygen in air, in the alveolar space is at a higher concentration than that in the blood capillaries.

It therefore first **dissolves** in the **water layer** in the alveolar lining then diffuses across the alveolus and then the capillary walls into the **red blood cells.**

This becomes **oxygenated** blood which is carried to the heart by the pulmonary vein.

Carbon dioxide in the blood diffuses across the capillary and alveolus walls into the alveolar space and is eventually expelled during **exhalation**.

# NB:

Gaseous exchange at the alveolus takes place between the phases of inhalation and exhalation.

***The alveolus is a suitable point for gaseous exchange because:***

- ✓ It is supplied with blood which carries the gases being exchanged.
- ✓ It has a very thin wall across which gases diffuse between it and the blood.
- ✓ It is lined with a thin film of moisture to dissolve the diffusing gases.
- ✓ A ventilation process brings in and takes away air containing the gases being exchanged.
- ✓ It has a very large number of alveoli to increase their surface area for gaseous exchange.

# Effect of smoking on the respiratory system

Tobacco smoke contains harmful chemicals like **Tar** (*sticky substance that coats the lungs and contains cancer-causing chemicals*) that **paralyses the cilia (***tiny hair-like structures that clear mucus and debris from lungs***)** in the respiratory tract and stops their movement.

In addition, tobacco smoke **increases the production of mucus** in the air ways, leading to congestion and **Chronic cough**.

A cough by a smoker is an attempt to remove the excess mucus from the respiratory system.

Besides irritating the trachea and bronchi, smoke particles interfere with the uptake of oxygen in the air sacs.

When cigarette **smoke is inhaled**, about one-third of the particles remain in the alveoli,

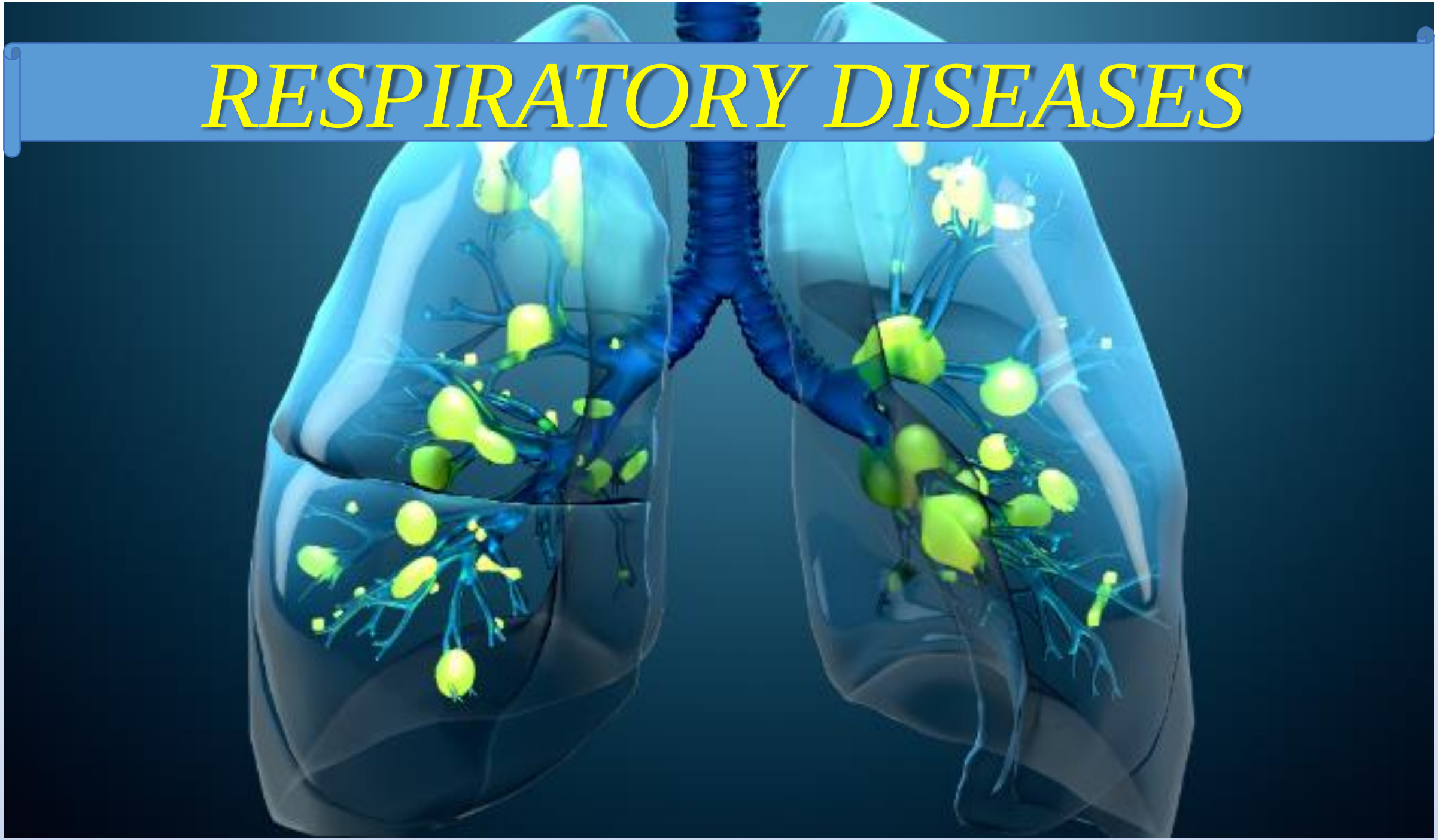
these **break down the walls of the air sacs** and causes the formation of inelastic tissue.

This reduces the functional area of the respiratory surface and in severe cases may lead to a disease called **Emphysema**. In some cases, **Lung Cancer** also develops.

Smoking also contributes to development of interstitial lung diseases, which involve scaring and inflammation of the lung tissue.

**NB:** Phagocytic cells called **macrophages** can slowly remove many of the particles.

# *RESPIRATORY DISEASES*



# Respiratory diseases

The respiratory system is affected by many diseases and disorders.

Some of these are caused by **micro-organisms** while others are **genetic**. The most common respiratory diseases are:

- **Tuberculosis**
- **Asthma**
- **Pneumonia**
- **Bronchitis**

**. Emphysema**

- **Whooping cough**
- **Common cold**
- **Influenza**

**Throat cancer**

**Chronic cough**

# Bronchitis

This is an infection of the inner walls of the bronchi.

It is caused by **bacteria** or **air pollutants** such as **smoke** in inhaled air.

The infection causes the mucous membrane in the respiratory tract to produce excess mucus, thus air passage to the alveoli becomes blocked with mucus.

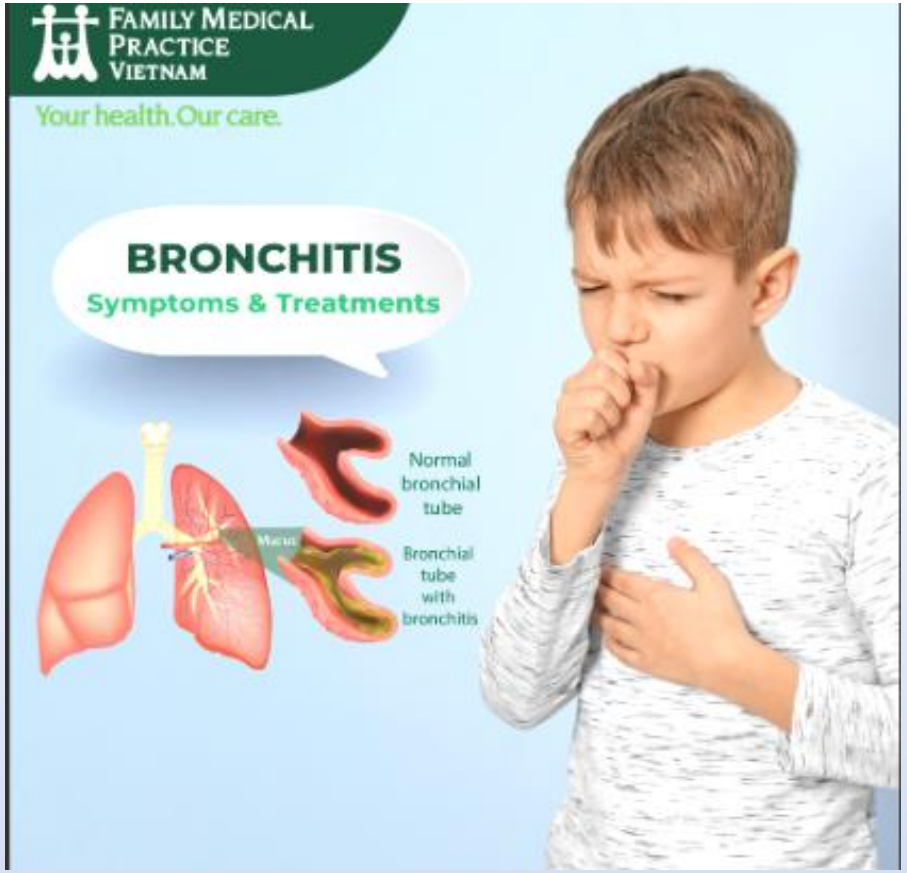
Bronchitis may be **acute** or **chronic**.

Acute bronchitis starts quickly and stops after a few days. The symptoms of acute bronchitis are like those of a cold.

Chronic bronchitis starts slowly and lasts for a long time. It is a more serious kind of infection. It is commonly caused by smoking and air pollution.

# Symptoms *of* bronchitis

- Secretion of excess mucus
- Coughing
- Difficulties in breathing.




## Prevention and treatment

- Acute bronchitis is treated by simple measures that include: getting plenty of rest, drinking lots of fluids and taking a cough syrup.
- People with chronic bronchitis should take antibiotics every time they have a cold with a fever.
- A doctor should be consulted at the early stages of bronchitis.
- Avoid smoking whether directly or passively.
- Avoid polluted air.

# *Emphysema*

This results from long untreated bronchitis where the bronchioles in the lungs become blocked.

This causes damage to **delicate walls of the alveoli** due to high pressure when coughing.


The patient becomes weak due to insufficient oxygen supply to tissues.

Running and walking can prove to be hard when one has this condition.

# Prevention and treatment

Emphysema is treated according to the severity of symptoms.

- ✓Bronchodilators e.g. albuterol, salmeterol are normally given to help relieve coughing, shortness of breath and breathing problems. (help relax and open air ways)
- ✓Oxygen therapy, for patients with severe emphysema and low blood oxygen levels, supplemental oxygen can help improve breathing and overall oxygen levels

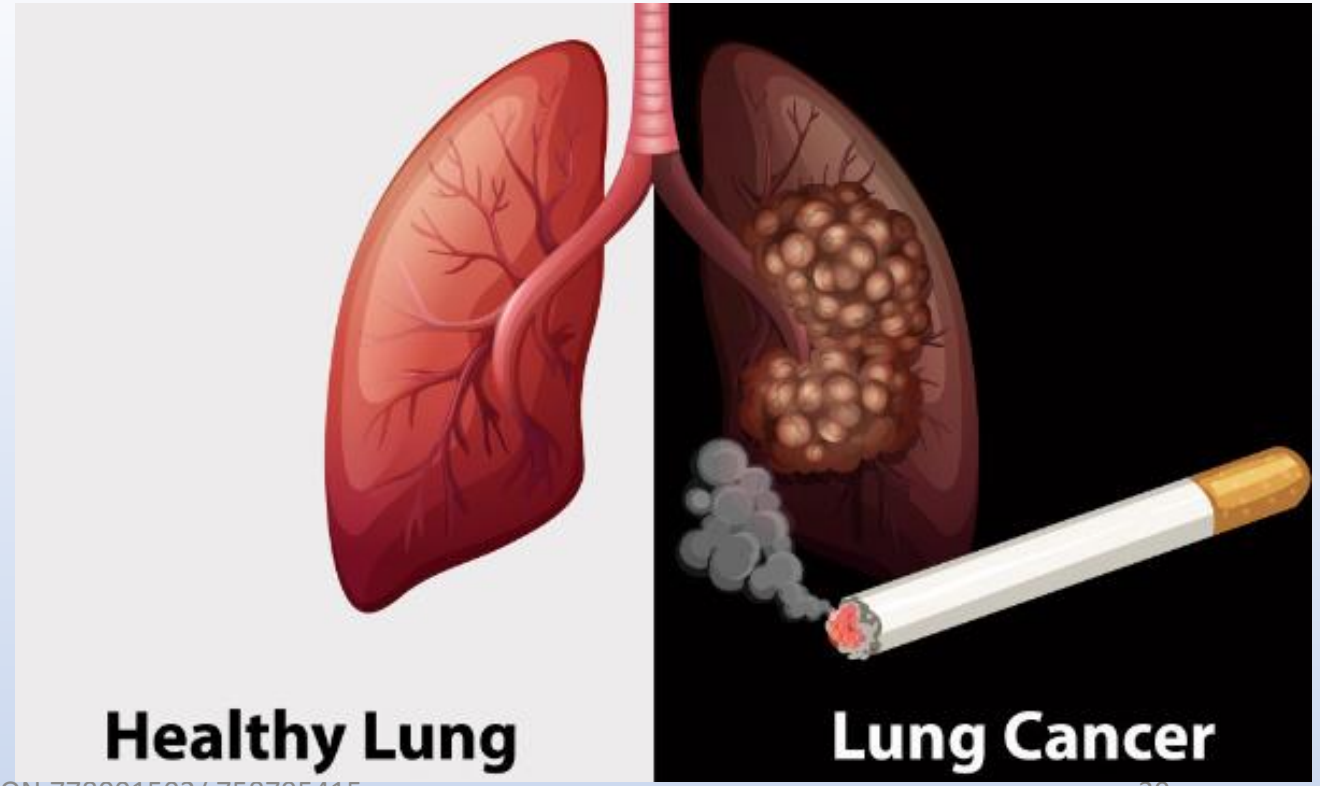
- ✓Early treatment of bronchitis with antibiotics to prevent secondary infection can help to prevent emphysema.

# Lung cancer

Tobacco smoke contains a number of **carcinogens**,

these cause **mutations** that lead to uncontrolled mitosis and formation of **tumours**.

This is called lung cancer



# Symptoms

- ✓Persistent cough (Cough that does not go away or worsens over time)
- ✓Blood in the sputum resulting from damage of lung tissues caused by a tumour
- ✓Shortness of breath because tumour is obstructing the airways
- ✓Wheezing noises as air is forced along airways obstructed by the tumour
- ✓Chest pain, pain that may be persistent and worsen with deep breathing, coughing or laughing
- ✓Frequent respiratory infections, recurring bronchitis or pneumonia

# Treatments

Treatments vary but mainly include

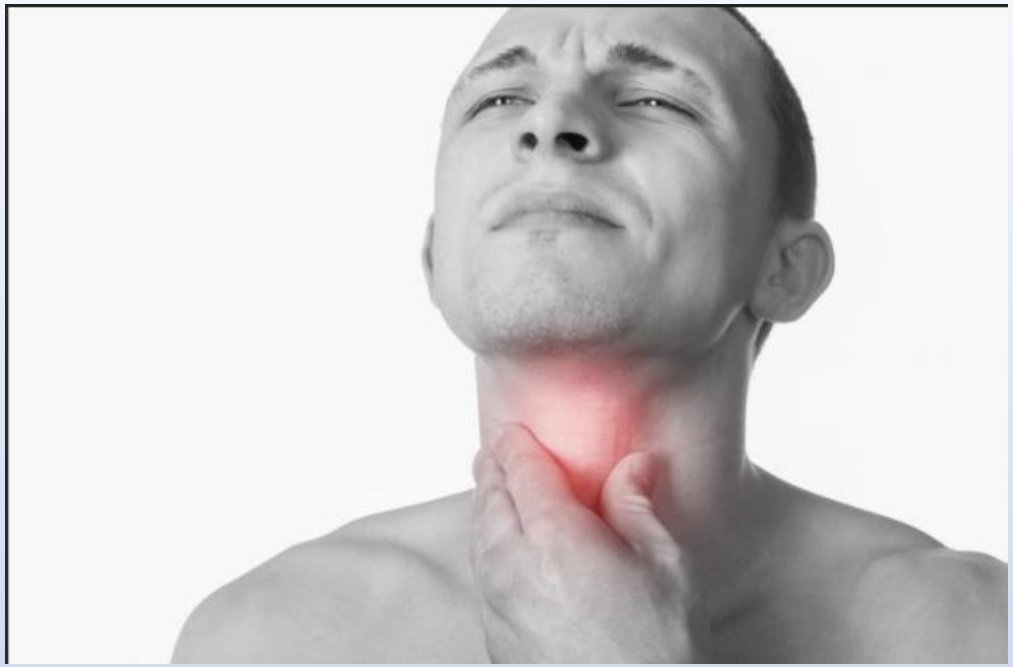
1. Surgery, removal of one lobe of the lung, removal of an entire lung
2. Chemotherapy, use of drugs to kill cancer cells
3. Radiation therapy, use of high-energy rays to kill cancer cells
4. Targeted drug therapy, use of drugs that target specific genetic mutations or proteins in cancer cells
5. Immunotherapy, boosts the immune system to fight cancer

# *Throat cancer*

Refers to cancer that develops in the throat(pharynx), voice box(larynx) or tonsils.

## *Signs and symptoms*

- ✓Persistent sore throat
- ✓Difficulty in swallowing
- ✓Hoarseness or voice changes
- ✓Lump or mass in the neck or throat
- ✓Chronic cough
- ✓Bleeding in the mouth or throat



# *Prevention and treatment*

- ✓Quit or avoid smoking
- ✓Maintaining good oral hygiene
- ✓Vaccination against HPV since Human papillomavirus infection is one of the risk factors for throat cancer
- ✓Eating a diet rich in fruits and vegetables
- ✓Regular medical check-ups if you are at risk.

***Note:*** for treatment, refer to lung cancer

# END

## BIOLOGY IS LIFE

## SLIDES PREPARED

## BY TR. PETER L OKION