Respiration

What is Respiration?

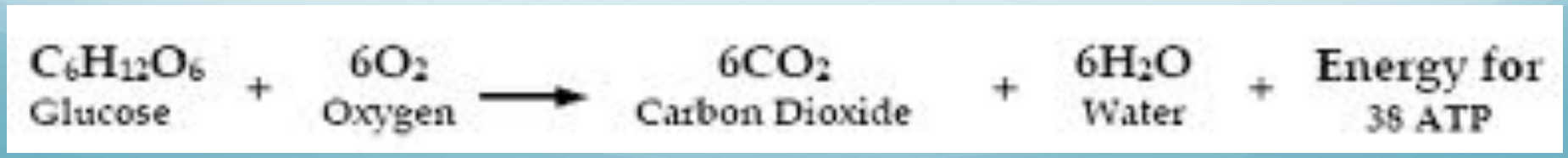
- It is a process that converts energy in food into a form which the body can “use” more easily.
- It involves the oxidation of food substances with the release of energy in living cells
- Oxidation is a chemical reaction involving the loss of electrons, addition of oxygen, or the loss of hydrogen
- There are 2 forms of respiration: aerobic and anaerobic

Why do organisms respire?

- Green plants transform light energy from the Sun during photosynthesis into chemical energy.
- Animals obtain this chemical energy in the form of stored (potential) energy by feeding on green plants.
- Since the energy is locked up in the organic food molecules, the organism will have to break them down to release this energy.
- This breakdown of complex organic substances is by oxidation - respiration

Aerobic respiration

- Aerobic respiration is the breakdown of food substances in the presence of oxygen with the release of a large amount of energy
- Carbon dioxide and water are released as waste products
- Many reactions are involved and each reaction is catalysed by an enzyme system
- Mitochondria are importance in aerobic respiration
- Most animals, including man, and green plants respire aerobically

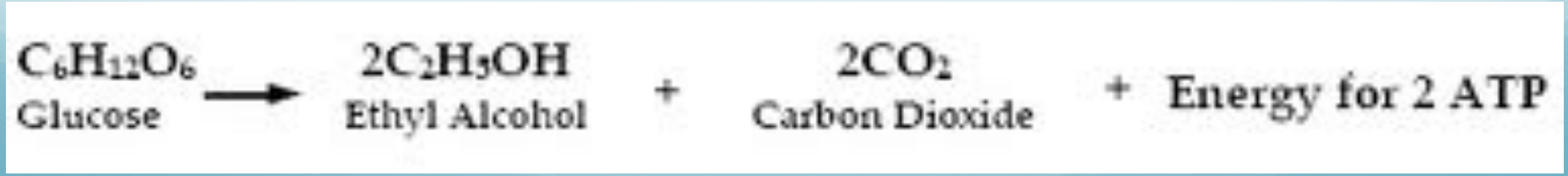


Energy yield from glucose

- When glucose is broken down during aerobic respiration, some of its energy is used to form another molecule called adenosine triphosphate or ATP.
- ATP is a quick source of a small amount of energy.
- In a living cell, ATP molecules are used to drive cellular processes.
- To make 1 molecule of ATP requires 30 kJ of energy.
- 1 mole of glucose yields 3 000 kJ of energy.

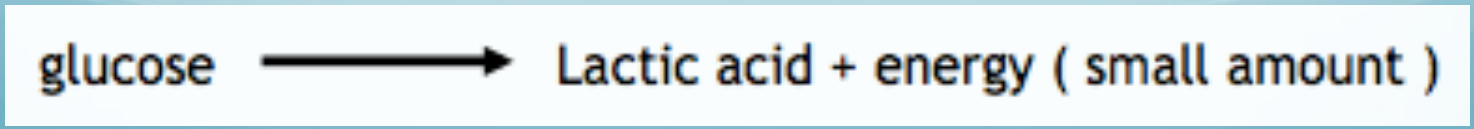
Anaerobic respiration

- Anaerobic respiration is the breakdown of food substances with the release of a comparatively small amount of energy in the absence of oxygen
- Yeast can respire both aerobically and anaerobically.
- Anaerobic respiration in yeast is called fermentation
- The glucose molecule is only partially broken down.
- The ethanol produced still contains much energy.
- This explains why a small amount of energy is set free.



Anaerobic respiration in muscles

- Vigorous muscular contractions forced the muscle cells to execute anaerobic respiration to produce extra energy. Lactic acid is formed in the process.
- This small amount of energy, together with the energy produced in aerobic respiration, is sufficient to keep the muscles contracting.
- However, due to insufficient oxygen, lactic acid slowly builds up in the muscles. The muscles are said to be experiencing an oxygen debt.
- Lactic acid is toxic, and may reach a concentration high enough to cause muscle fatigue. The muscular pain experienced is due to the lactic acid.
- A period of rest is necessary to remove lactic acid from the muscles to be transported to the liver.
- Some of the lactic acid is oxidized to produce energy, which is then used to convert the remaining lactic acid to glucose.



Anaerobic vs Aerobic Respiration

Aerobic Respiration	Anaerobic Respiration
Oxygen needed	Oxygen not needed
A lot of energy released	Less energy released
Carbon dioxide produced as byproducts	Lactic acid or ethanol produced as byproducts

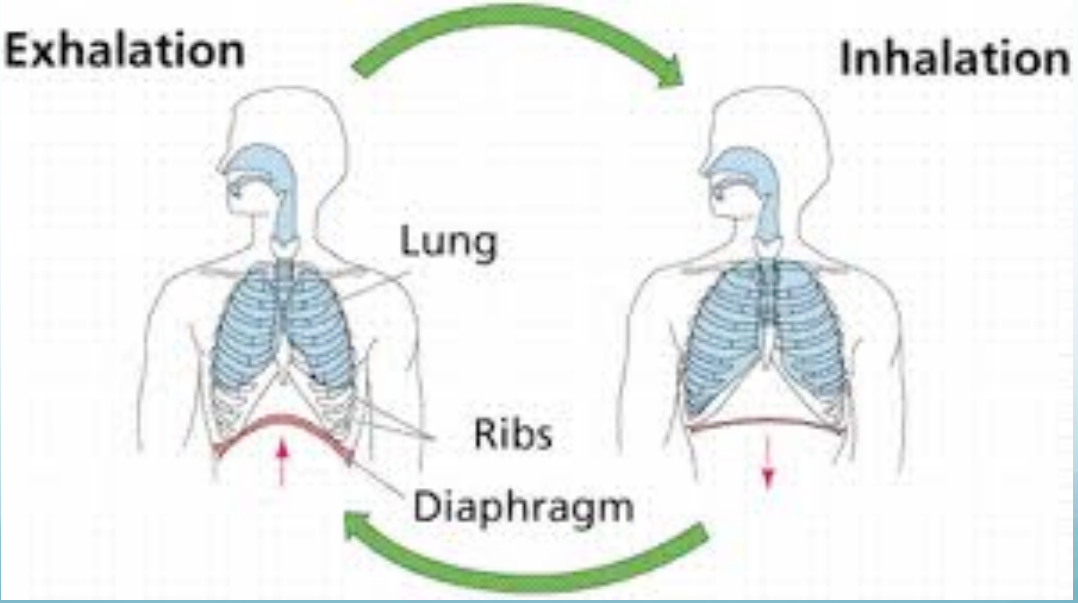
Aerobic Respiration

Aerobic respiration involves two processes

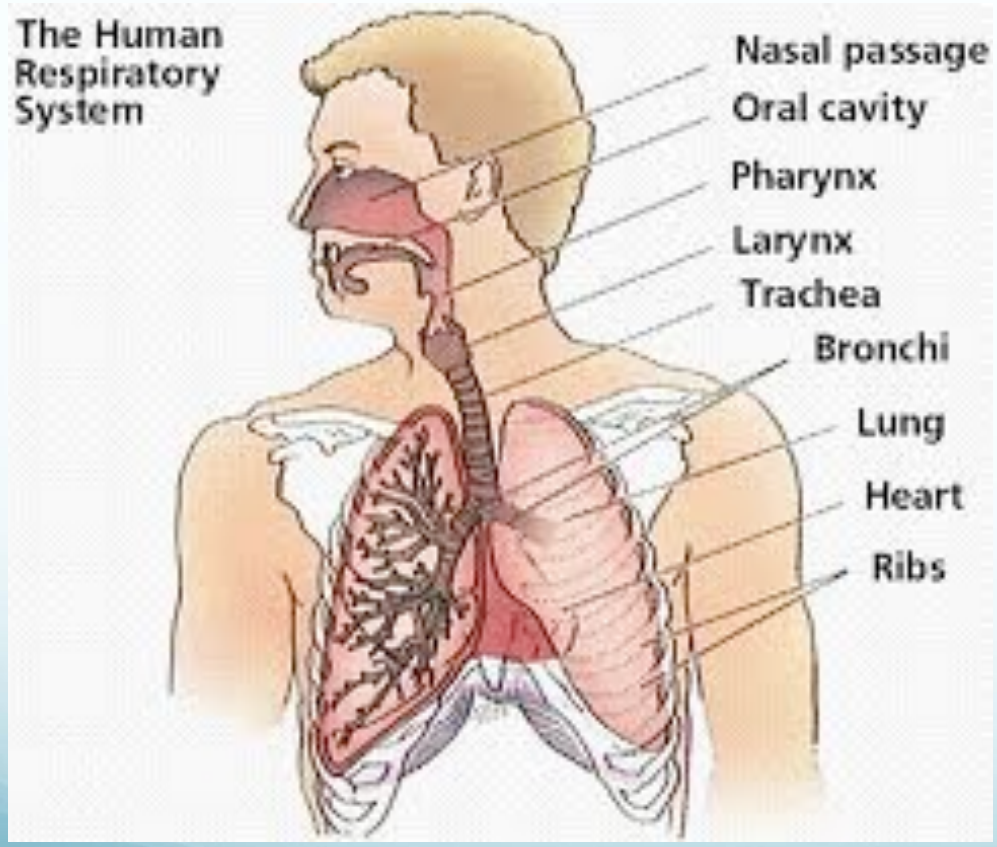
- **tissue respiration**
  - The oxidation of organic food molecules with the release of energy, carbon dioxide and water.
  - It occurs within living cells and tissues of an organism and is termed *tissue* or *internal respiration*.
  - All the energy of animals makes use of is made available by this means.
- **gaseous exchange**
  - Oxygen is brought to the cells of an organism through this means.
  - The transfer of oxygen from the surroundings to the cells and the transfer of products of respiration from the cells back to the surroundings is called gaseous exchange.
  - Breathing is part of the process exchange.

Breathing Mechanisms

- The breathing motions of an animal consist essentially of two phases :
- the taking in of air – inspiration or inhalation
- the giving out of air – expiration or exhalation



Human Respiratory System



The organs involved in gas exchange are the two lungs in the thorax and the air passages leading to them.

The air passages consist of

1.The nasal passages

2.Pharynx

3.Larynx

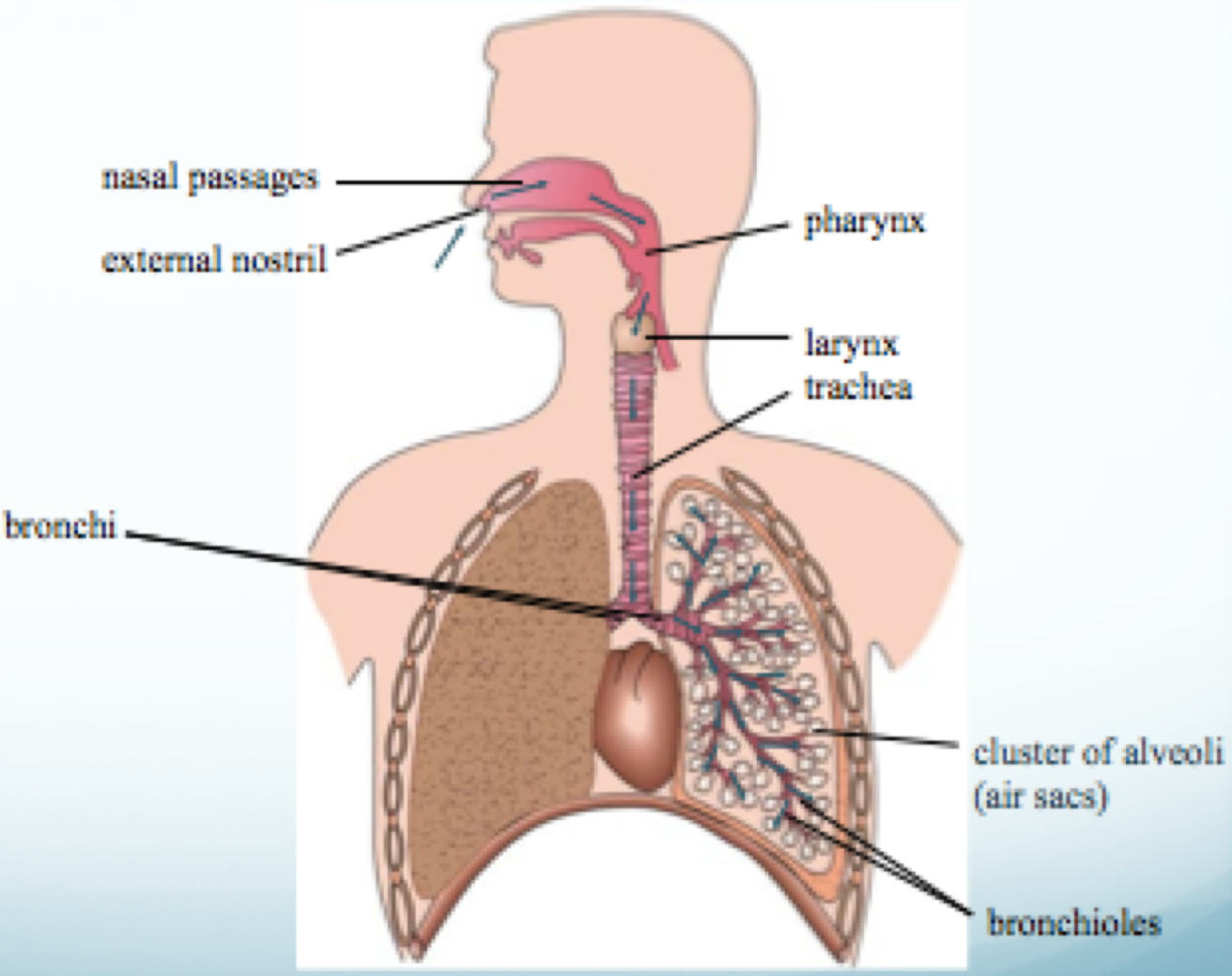
4.Trachea

5.Bronchi

6.Bronchioles

Passage of Air

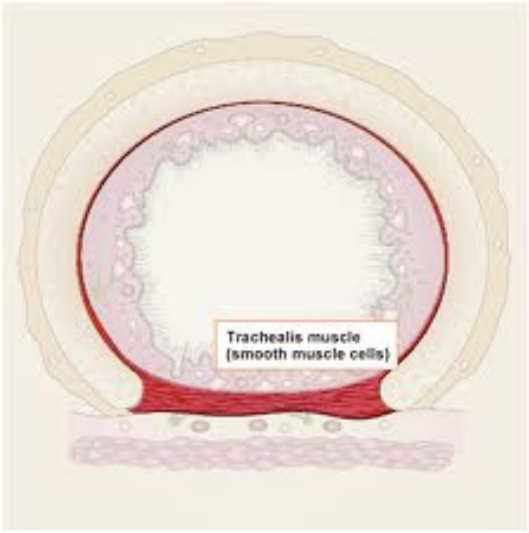
atmosphere
↓
external nostril
↓
nasal passages
↓
pharynx
↓
larynx
↓
trachea
↓
bronchi
↓
bronchioles
↓
alveoli

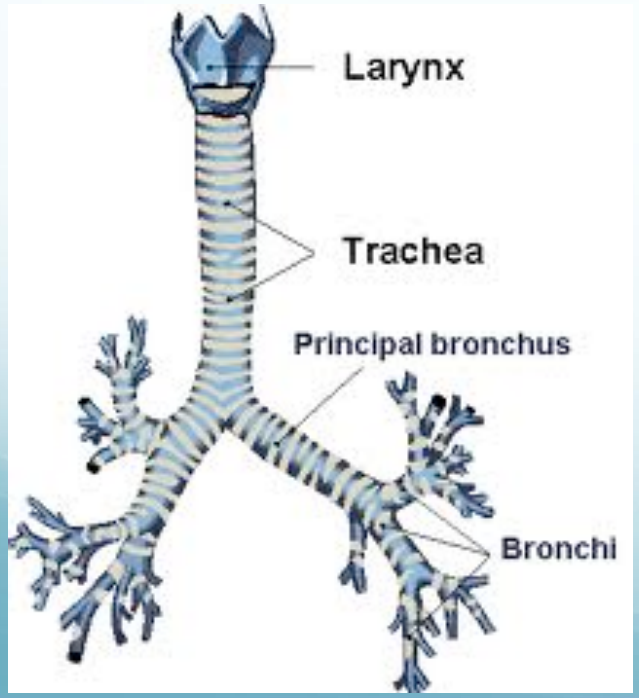


Advantages of breathing through nose

1. Dust and foreign particles, including bacteria in the air, are trapped by the hairs in the nostrils as well as by the mucus on the mucous membrane
2. As the air passes through the nasal passage it is warmed and moistened before it enters the lungs
3. Harmful chemicals may be detected by the sensory cells in the mucous membrane

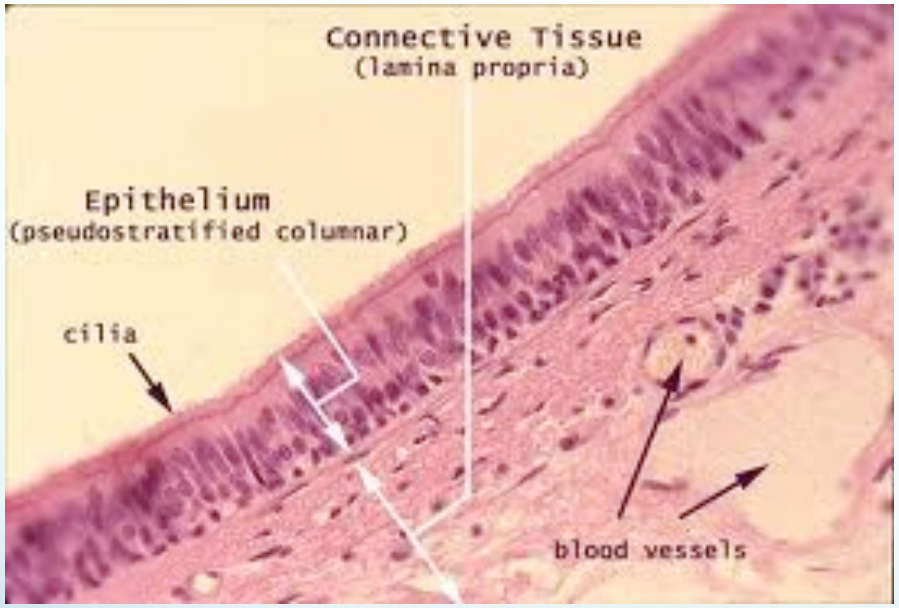
The trachea





- At the end of the nasal passages are 2 openings, the internal nares, through which air passes into the pharynx. From the pharynx, the air passes first into the larynx and then into the trachea through an opening known as the glottis
- The trachea lies in front of the oesophagus and extends from the larynx downwards into the chest cavity
- It is supported by C-shaped rings of cartilage which ensure that it is always kept open
- The lower end of the trachea divides into 2 tubes – the bronchi, one to each lung
- The right bronchus divides into 3 bronchial tubes, one to each of the 3 lobes of the right lung
- The left bronchus divides into 2 as the left lung has only 2 lobes

The trachea

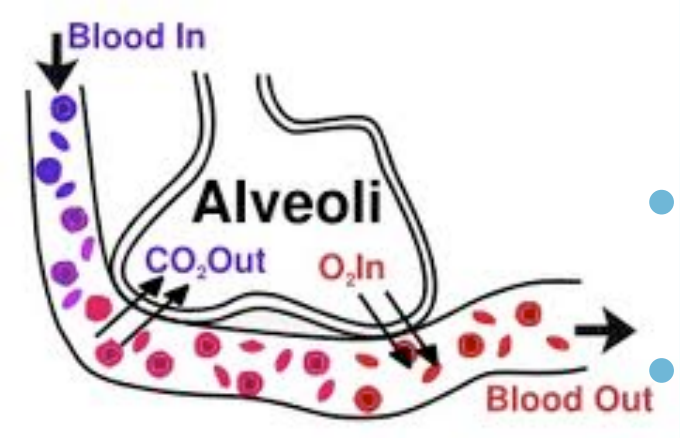


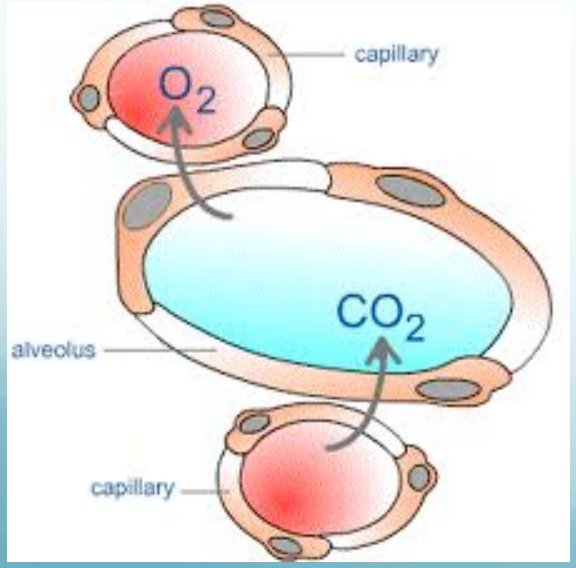
- The epithelium lining the thinner walls of the trachea and bronchi bears cilia
- There are also gland cells that secrete mucus which traps dust particles and bacteria
- The cilia help to sweep these particles up the bronchi and trachea into the pharynx

Bronchi

- Within the lungs, the bronchial tubes divide repeatedly, giving rise to smaller and smaller tubes
- The smallest bronchial tubes are known as bronchioles and are not supported by cartilage
- Each bronchiole ends in a cluster of air sacs or alveoli
- The alveolar walls are very thin, moist, and well-supplied with blood capillaries – all suited for gaseous exchange
- The elastic nature of the lungs enables them to expand and contract easily during breathing
- Gaseous exchange takes place through the walls of the alveoli
- Thousands of alveoli are found in the lungs, providing a very large surface area for gaseous exchange

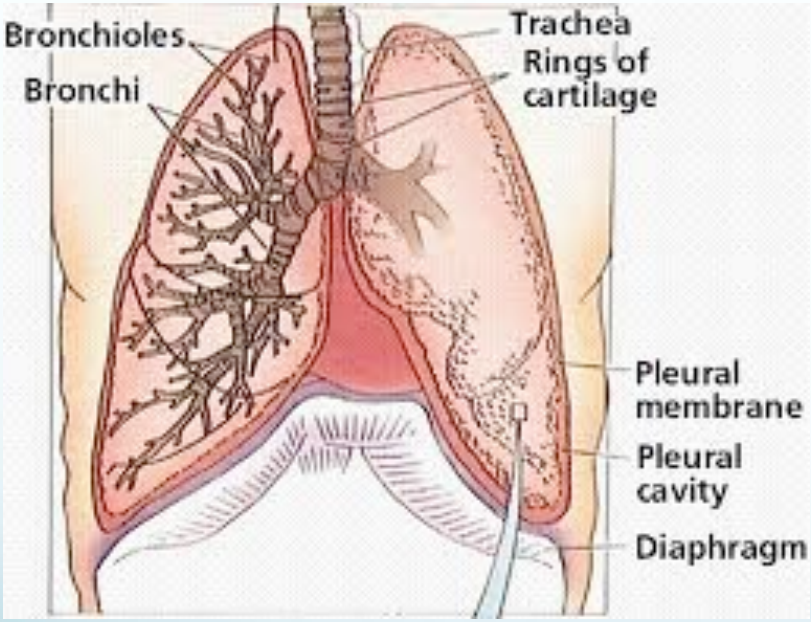
Inside the alveolus





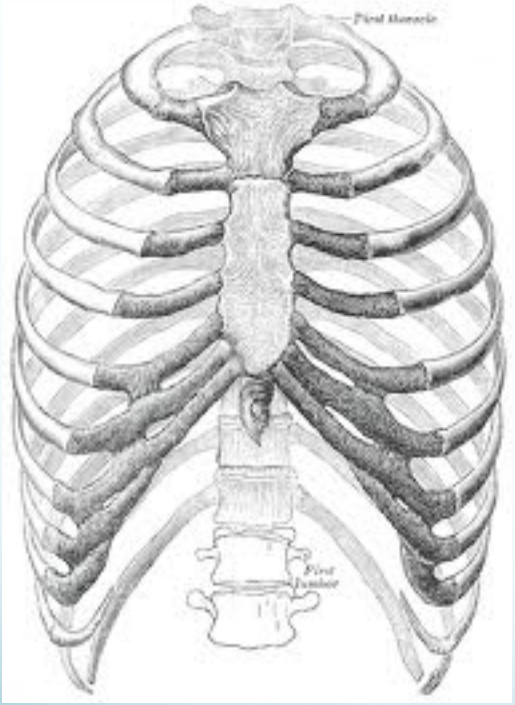
- A concentration gradient of oxygen and carbon dioxide is present between the lungs and the alveolar air
- Alveolar air has a high concentration of oxygen
- Blood entering the lungs has a low concentration of oxygen
- Oxygen moves from the alveolar air into the blood down its concentration gradient
- It does so by dissolving in the moisture lining the alveolar walls
- Diffusing through the alveolar and capillary walls and into the blood

The lungs



- Each lung lies in the pleural cavity, and when expanded both lungs almost fill it
- The pleural cavity is lined by 2 transparent elastic membranes called the pleura or pleural membranes
- The inner pleuron covers the lung, while the outer one is in contact with the walls of the thorax and the diaphragm
- The thin layer of lubricating fluid between the pleura allows the membranes to glide over each other easily when the lungs expand and contract during breathing

The ribs



- The chest wall is supported by the ribs, which are attached to the backbone dorsally in such a way that they can move up and down
- In front, the ribs are similarly attached to the chest bone or sternum
- In man, there are 12 pairs of ribs but only the first 10 pairs (from top) are attached to the sternum, while the remaining pairs being free ribs
- Between the ribs are 2 sets of muscles – external and internal intercostal muscles
- When the external intercostal muscles contract, the internal intercostal muscles relax and vice versa

The thorax

- The thorax is separated from the abdomen by a dome shaped sheet of muscle and elastic tissue – diaphragm
- When the diaphragm muscles contract, the diaphragm flattens downwards and when they relax the diaphragm arches upwards again
- The working of the intercostal muscles and the diaphragm changes the volume of the thoracic activity

Alveoli vs Capillaries

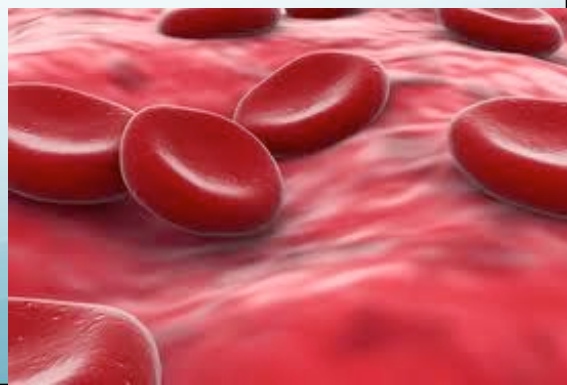
Similarities:

- Both are important sites for exchange of substances
- Both have thin cell walls to for rapid diffusion of substances
- Both provide a large surface for rapid exchange of substances

Alveoli	Capillaries
Part of the respiratory system	Part of the circulatory system
For the exchange between the blood and the atmospheric air	For the exchange of substances between the blood and the tissue fluid
For the exchange of carbon dioxide and oxygen	For the exchange of carbon dioxide, oxygen, dissolved food substances and other waste products

Exchange of oxygen

- In the blood, oxygen binds reversibly with haemoglobin on the red blood cells to form oxyhaemoglobin
- When the blood passes into the systemic circulation and flows through oxygen poor tissues
- This reaction reverses and oxyhaemoglobin disassociates to give oxygen and haemoglobin
- The oxygen then diffuses through the capillary walls into tissue fluid and is taken up by the cells



Exchange of carbon dioxide

- Large amounts of carbon dioxide are produced by tissue cells in respiration
- This carbon dioxide diffuses in the tissue fluid, through the capillary walls, into the blood
- The carbon dioxide enters the red blood cells which contain the enzyme carbonic anhydrase, which catalyses the reaction between carbon dioxide and water to give carbonic acid
- The carbonic acid is converted into hydrogen carbonate ions
- Hydrogen carbonate ions diffuse out of the red blood cells into the plasma
- Most of the carbon dioxide is transported in the form of hydrogen carbonate in blood
- A small amount of carbon dioxide (not in the hydrogen carbonate form) is carried as it is, dissolved in the blood plasma
- As blood reaches the lungs, hydrogen carbonate ions diffuse back into the red blood cells
- There they form carbonic acid again which decomposes into carbon dioxide and water.

Exchange of carbon dioxide

- Alveolar air has a low concentration of carbon dioxide
- Blood entering the lungs has a high concentration of carbon dioxide
- Carbon dioxide moves from the blood into the alveolar air, down its concentration gradient
- It does so by dissolving in the moisture lining the alveolar walls
- Diffusing through the alveolar and capillary walls and into the blood

Breathing mechanisms

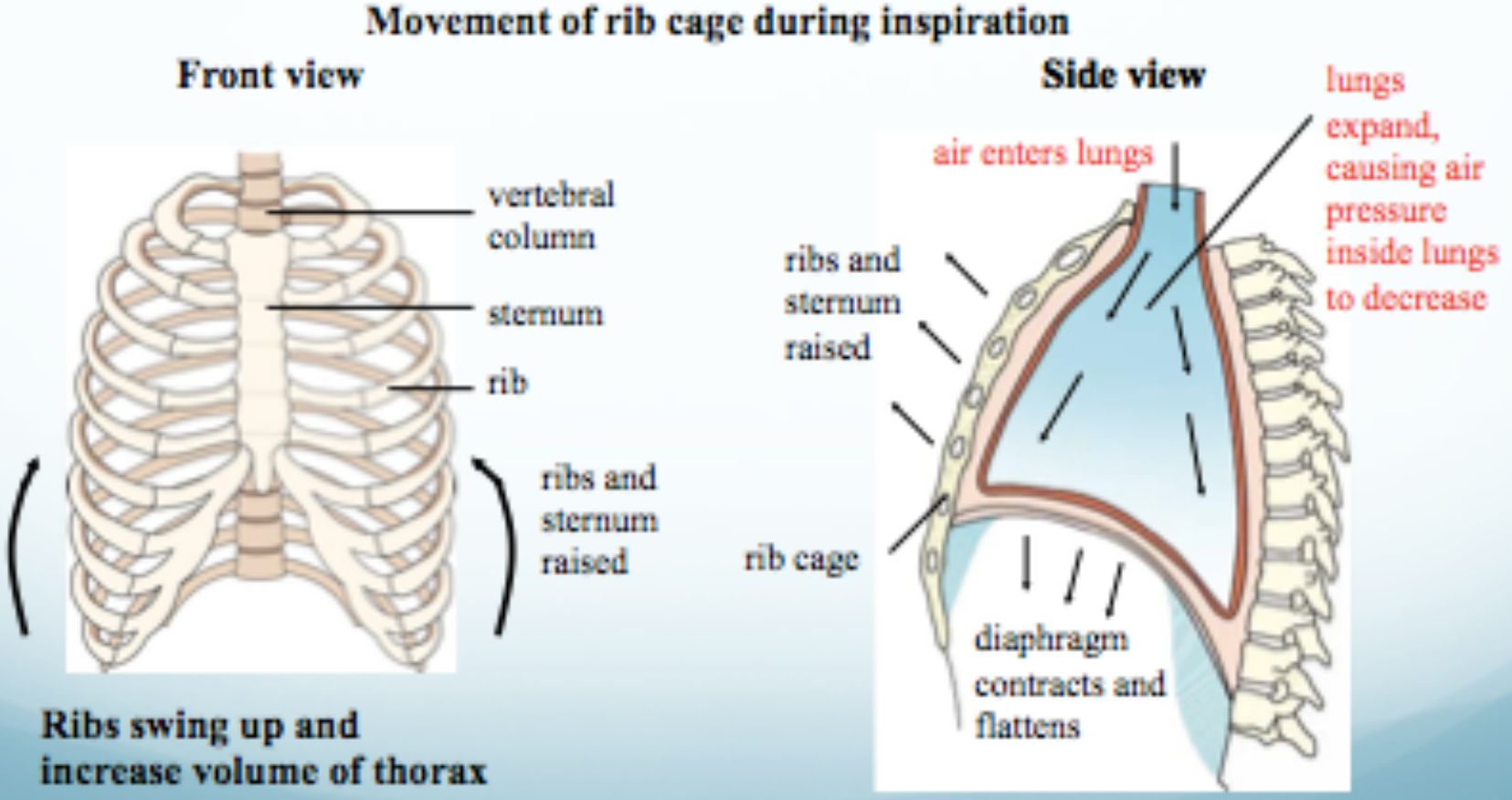
Inspiration or inhalation

- When we breathe in, the external intercostal muscles contract while the internal intercostal muscles relax
- As a result, the ribs swing upwards and outwards
- Accordingly, the sternum us moved up and further away from the backbone.
- This increases the dorsoventral diameter of the thorax
- The upward movement of the ribs also increases the breadth of the thorax
- As the ribs move upwards, the diaphragm contracts and flattens and so enlarges the thoracic cavity

Breathing mechanisms

- Increasing the volume of the thoracic cavity lowers the pressure inside the thoracic cavity so that it is now less than the external air pressure
- As the thoracic activity enlarges, the air pressure in the alveoli causes the lungs to expand to fill up the enlarged space
- The expansion of the lungs reduces the air pressure in the alveoli
- The alveolar air pressure is now at a lower pressure than the atmospheric air which rushes into the lungs until the air pressure in the lungs and that in the atmosphere are equal
- Thus, the air is actually sucked into the lungs

Inhalation


Movement of rib cage during inspiration
Front view
vertebral column
sternum
rib
ribs and sternum raised
Ribs swing up and increase volume of thorax
Side view
air enters lungs
lungs expand, causing air pressure inside lungs to decrease
ribs and sternum raised
rib cage
diaphragm contracts and flattens

Breathing mechanisms

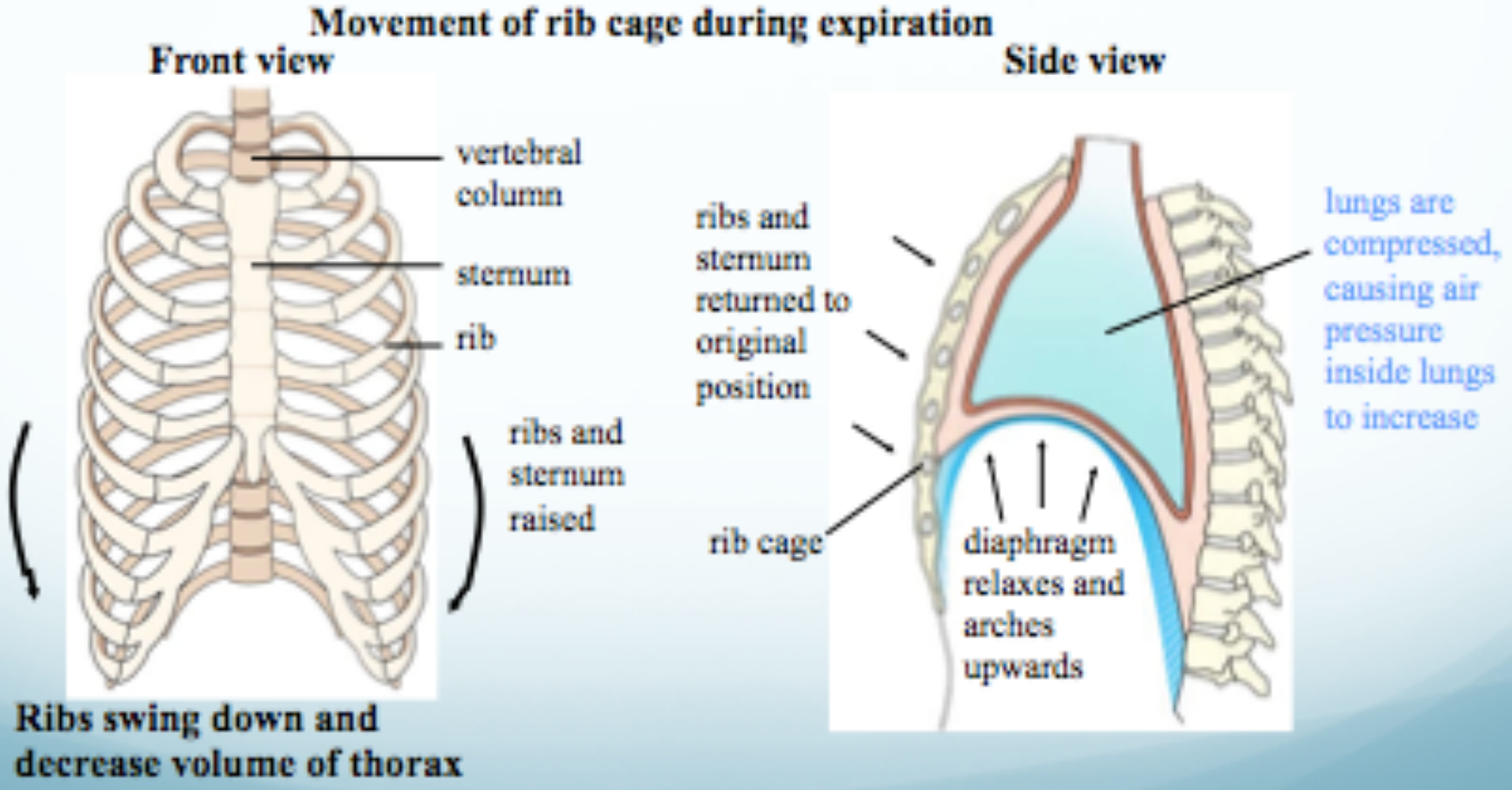
- Then there is a short pause during which gaseous exchange between the alveolar air and the blood occurs
- Oxygen dissolves in the moisture lining the alveolar walls
- The dissolved oxygen then diffuses into the blood where it combines with hemoglobin to form oxyheomoglobin
- At the same time, carbon dioxide diffuses in the opposite direction

Breathing mechanisms

Expiration or exhalation

- Expiration follows
- The diaphragm relaxes and arches upwards
- The external intercostal muscles relax while the internal intercostal muscles contract
- The ribs and sternum return to their original positions pressing on the lungs
- Air is forced out of the lungs as the latter are compressed

Expiration


Movement of rib cage during expiration
Front view
Side view
vertebral column
sternum
rib
ribs and sternum raised
Ribs swing down and decrease volume of thorax
ribs and sternum returned to original position
rib cage
diaphragm relaxes and arches upwards
lungs are compressed, causing air pressure inside lungs to increase

How to remember?

When you inhale, you…

Relax your
Internal intercostal muscles and
Contract your
External intercostal muscles

RICE

When you exhale, your…

External intercostal muscles
Relax and your
Internal intercostal muscles
Contract

ERIC

Gaseous exchange in the lungs

- By diffusion
- Blood entering the lungs contains little oxygen but much carbon dioxide
- Air taken in during respiration contains much oxygen but little carbon dioxide
- Such a diffusion gradient with an oxygen concentration higher in the alveolar air than in the blood and a carbon dioxide concentration higher in the blood than in the alveolar air can be maintained in 2 ways:
  - A continuous flow of blood through the blood capillaries
  - Breathing air in and out of the alveoli

Gaseous exchange in the lungs

- The one-cell thick membrane separating the blood capillaries from the alveolar air is permeable to the 2 gases, allowing easy diffusion of these gases
- As the alveolar air contains more oxygen than the blood, the oxygen will diffuse into the blood after dissolving in the moisture lining the alveolar walls
- The oxygen combines with haemoglobin in the red blood cells to form oxyhaemoglobin - This reaction is reversible
- Whether it goes forward or backward depends on the amount of oxygen in the surroundings
- In the lungs where the oxygen concentration is high, the reaction is shifted to the right and oxyhaemoglobin is formed
- When the blood passes through oxygen-poor tissues, the reaction is shifted to the left, so that oxygen is liberated. Oxygen then diffuses through the walls of the blood capillaries into the cells

Gaseous exchange in the lungs

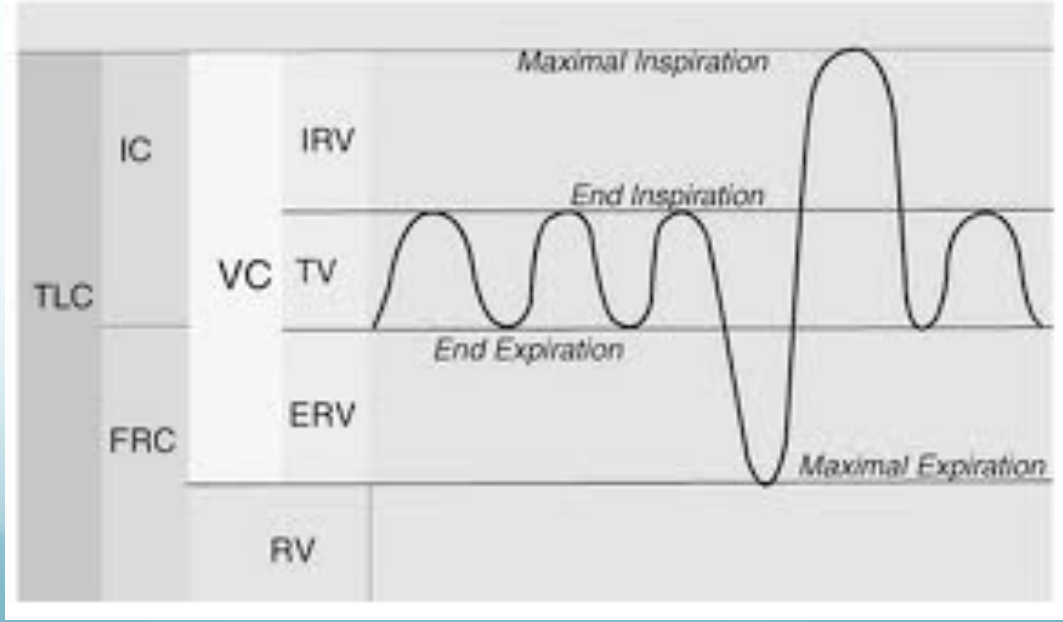
- Carbon dioxide produced by tissue cells diffuses into the blood plasma where it is carried in the form of hydrogen carbonate ions to the lungs
- In the lungs, the hydrogen carbonate is converted back to carbon dioxide
- Carbon dioxide diffuses out of the blood capillaries into the alveolar cavities
- Some water evaporates from the walls of the alveolar
- Some heat also escapes from the blood into the alveolar air

Lung capacities

- Only some of the air in the lungs is changed in each breathing cycle
- The amount of air changed varies with the depth of breathing
- Estimated that about 500cm^3 of air enters the lungs in each normal breathing cycle, and about the same volume of air is breathed out – **tidal air**
- By taking a deep breath, an extra volume of air, in addition to tidal air, is taken in – **complemental air** – about 1500cm3
- Similarly, about 1500cm^3 of air can be forced out after normal expiration – **supplemental air**
- By taking the deepest breath, can take in a total of about 3500 to 4000cm^3 of air – **vital capacity of the lungs**

Vital capacity

- Vital capacity = tidal air + complemental air + supplemental air
- No matter how hard a person tries to force all the air out of his lungs, there is always some left behind – **residual air** – about 1500cm^3



Stimulus for breathing

- A high concentration of carbon dioxide in the blood or in the alveolar air, not a lack of oxygen
- No breathing movements occur when there is too little carbon dioxide in the lungs

Irritant particles

- When breathing is normal (via the nose), most of the dust particles are filtered off by hairs in the nose or trapped in mucus
- Sometimes when irritant particles enter the respiratory passages, this causes an automatic violent coughing reaction, resulting in their expulsion
- However, when there is an excessive amount of particles being breathed in, the respiratory system cannot remove them.
- Long-term exposure to irritant particles can lead to chronic symptoms.
- Symptoms: respiratory tract irritation, coughing, shortness of breath.
- Vital capacity is **reduced**.

Irritants

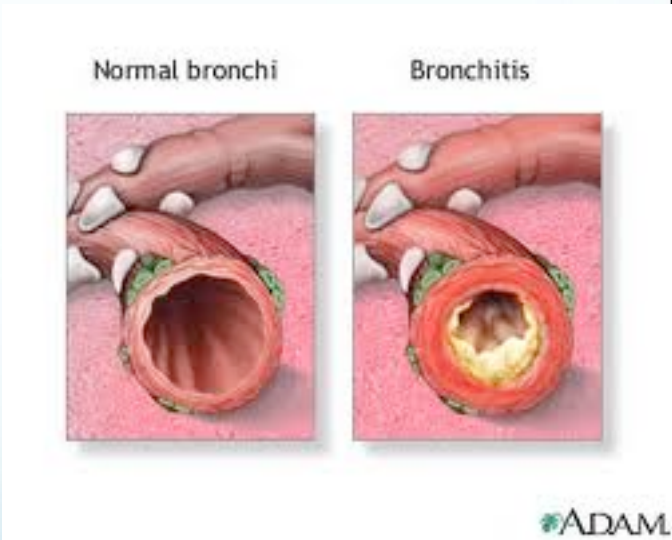
- **Tar**
  - contains carcinogenic chemicals which lead to uncontrolled cell division of the epithelium - lung cancer, blockage of bronchioles and alveoli.
  - Paralyzes cilia due to
    - Tar trapped in mucus cannot be removed easily.
- **Nicotine**
  - Causes addiction
  - Causes the release of adrenaline - increase in heartbeat and blood pressure
  - Thought to stabilize fibrin threads in blood - leads to unwanted blood clotting.
- **Carbon monoxide**
  - Formation of carboxyhaemoglobin→lowers efficiency of oxygen transport by RBCs.
  - Increases fatty deposits on the inner artery walls by making them more “sticky” - atherosclerosis
    - Atherosclerosis can also lead to thrombosis - unwanted blood clotting

Irritants

- Hydrogen cyanide, acrolein, formaldehyde
  - These irritants paralyze the cilia in the air passages.
- Acrolein can bind directly to DNA and cause mutations in p53, an important gene in preventing cancers.

Chronic Bronchitis

- Inflammation of the epithelium lining the bronchi.
- Increased production of mucus by goblet cells.
- Cilia are paralyzed and cannot clear the excess mucus/particles.
- Airways become blocked.
- Symptoms: coughing, shortness of breath, wheezing, bronchospasm.
- Vital capacity is **reduced** because complemental and supplemental air is reduced.



Emphysema

- Irritants from smoke trapped in mucus leads to coughing.
- Excessive coughing causes the partition walls between the air sacs to fuse together:
  1. Reduces surface area for gaseous exchange.
  2. The air sacs lose their elasticity.
- Lungs become filled with air.
- Symptoms: difficult breathing, wheezing, breathlessness
- Vital capacity is **reduced** because supplemental air is reduced.
- Residual air increases.

Recall! Inhalation

	Feature	Changes
1	Diaphragm	Contracts and flattens
2	External intercostal muscles	Contract
3	Internal intercostal muscles	Relax
4	Ribs	Move upwards and outwards
5	Sternum	Moves upwards and forwards
6	Volume of thoracic cavity	Increases
7	Lungs	Expand in respond to air pressure to fill up thoracic cavity
8	Air pressure of lungs	Decreases due to lung expansion
9	Air movement	Atmospheric pressure > lung pressure. Air enters lung

Recall! Exhalation

	Feature	Changes
1	Diaphragm	Relaxes and arches upwards
2	External intercostal muscles	Relax
3	Internal intercostal muscles	Contract
4	Ribs	Moves downwards and inwards
5	Sternum	Moves downwards and backwards into original position
6	Volume of thoracic cavity	Decreases
7	Lungs	Compressed by decrease in thoracic cavity volume
8	Air pressure of lungs	Increases as lungs are compressed
9	Air movement	Lung pressure higher than atmospheric pressure. Air forced out of lungs

Respiration vs Photosynthesis

	Respiration	Photosynthesis
energy	Energy is liberated	Energy is stored.
gases	Oxygen is used, carbon dioxide and water given off.	Carbon dioxide and water are used while oxygen is given off
Catabolic or anabolic	A catabolic process, resulting in breakdown of carbohydrate molecules.	An anabolic process, resulting in the building up of carbohydrate molecules.
frequency	Occurs at all times.	Occurs only in cells containing chlorophyll in the presence of sunlight.
Dry mass?	Results in loss of dry mass.	Results in gain of dry mass.