GASEOUS EXCHANGE IN ANIMALS

The majority of animals need oxygen in order to oxidize the organic materials and produce energy for cellular activities.

The oxidation of the food not only yields energy but also carbon dioxide which must be constantly removed from the body.

The process of moving oxygen into the body and carbon dioxide out of the body is called breathing in or ventilation. **Gaseous exchange** involves the passage of carbon dioxide through a respiratory surface. Diffusion is the main transport process involved in gaseous exchange.

Characteristics of the respiratory surfaces

1. They have a large surface area in order to increase the rate of diffusion
2. They are usually thin and permeable in order to reduce the resistance to diffusion
3. They are moist to dissolve the gases
4. They are well supplied with blood.

Types of respiratory surfaces in animals

Small animals such as amoeba use their entire body surface for gaseous exchange. They have a high surface area /volume ratio. As organisms increase in size, the surface area/volume ratio decreases, hence there is need to have special respiratory system or organs.

Gaseous exchange in lower animals

Protozoa and animals with relatively few cells like the coelenterates and worms don't breathe. They rely on diffusion a lone for exchange of gaseous between their bodies and the liquid environment in which they live.

Earth worms that live in soil have gaseous exchanges taking place in the skin which is thin and moist and has a good blood supply.

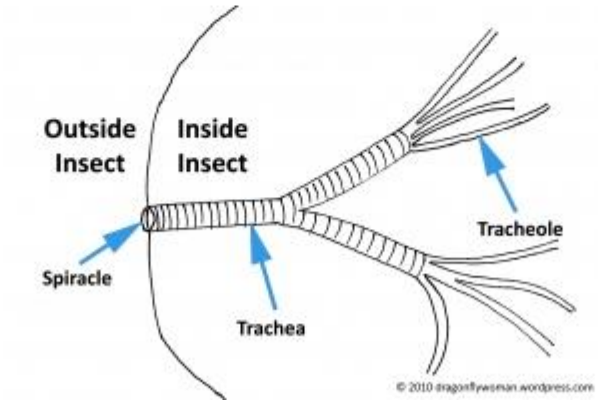
Gaseous exchange in insects

The respiratory system consists of a network of tubes forming the tracheal system. The tubes open to the outside through pores called spiracles located on the sides of the thorax and the abdomen. The tubes called the trachea are lined with cuticle and have spiral rings which prevent the walls from collapsing inwards.

The trachea is divided into smaller tubes called tracheoles which are closely associated with the tissues. Some insects have air sacs connected to the trachea. These air sacs can be inflated or deflated in order to facilitate gaseous exchange

Ventilation is brought about by the contraction and relaxation of the abdominal muscles. In locusts, air is drawn into the body through the thoracic spiracles and expelled through the abdominal spiracles.

Diagram



GASEOUS EXCHANGE IN AMPHIBIANS

Amphibians live in two environments air and water and are therefore adapted to gaseous exchange in land and in water hence are adapted for gaseous exchange in water and on land. Also show change of respiratory surfaces and organs as they develop from gills in tadpoles to lungs, skin and mouth cavity in adults.

Young tadpoles have external gills and older tadpoles have internal gills that work in a similar way to those of fish.

Adult amphibians use.

1**. Skin.**

The skin surface is always kept moist by secretions from mucus glands so that oxygen from the atmosphere can dissolve into the moisture and diffuses easily into the skin. Also the skin is well supplied with blood vessels so that oxygen easily diffuses into the blood and carbon dioxide out. Also the skin is thin to provide a short diffusion distance necessary for fast gas diffusion. Amphibians use the skin for gaseous exchange both on land and in water.

2. Lining of the buccal cavity

The lining of the mouth cavity (buccal) is only used when the amphibian is on land. The amphibian closes its mouth and glottis and opens its nostrils. It then lowers the floor of the buccal cavity, volume in the buccal cavity increases and therefore pressure decreases and air is forced into the mouth cavity via the nostrils. The lining of the buccal cavity is thin, moist and well supplied with blood vessels. Oxygen is diffuses into the blood and carbon dioxide diffuses out.

3. Lungs

Lungs are not used in gaseous exchange very frequently but when they are, air is first taken into the mouth cavity which is lowered. The nostrils are then closed and the floor of the buccal cavity raises which forces air into the lungs. Oxygen diffuses into the blood capillaries of the lungs as carbon dioxide diffuses out.

GASEOUS EXCHANGE IN FISH.

In fish the medium of exchange is water. The respiratory organs are in internal gills that extract oxygen from the water and expel carbon dioxide into it

Inhalation in fish

The floor of the mouth is lowered, increasing the volume of the mouth (buccal cavity), hence decreasing the pressure with in the mouth. Operculum closes, mouth opens and water enters through the mouth into the mouth cavity.

Exhalation in fish

Mouth closes, floor of the mouth is raised hence decreasing volume of the mouth and as a result the pressure with in the mouth increases, forcing water to move over the gills and as water is moving over the gills, oxygen from water diffuses into the gill filaments and carbondioxide diffuses out of the gill filaments into water. The high pressure also forces the operculum to open and water flows out.

FUNCTIONS OF EACH OF THE PARTS

- **Gill filament**: sites for gaseous exchange.
- **Gill rakes**: These filter large particles of the water before they reach and damage the gill filament.
- **Gill bar**: This provides support and attachment for the gill filaments.

Adaptation of gills for gaseous exchange

- Presence of numerous gill filaments to increase the surface area for gaseous exchange
- Each filament is supplied with a dense network of blood capillaries for efficient transport of gases
- Each filament is thin walled to reduce the distance across which gases diffuse
- The filaments are further sub divided into lamellae to increase the surface are for gaseous exchange

Gaseous exchange in bony fish (e.g. tilapia)

Gaseous exchange in fish takes place between the gills and the surrounding water. The gills are located in the opercular cavity covered by a flap of skin called the operculum. Each gill consists of a number of thin leaf like lamellae projecting from a skeletal base (brachial arch) situated in the wall of the pharynx.

Each gill is supported by a gill bar through which blood vessels send branches to the filaments.

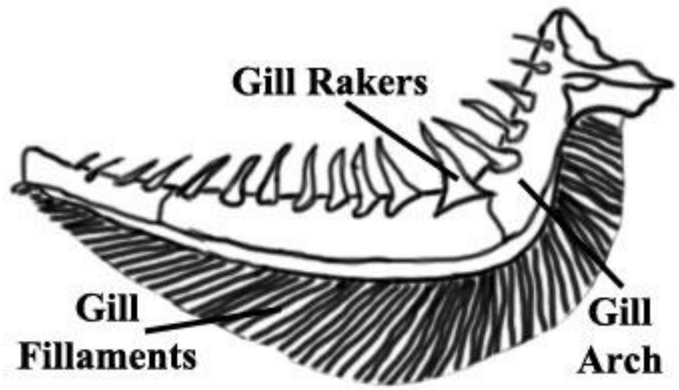
Diagram of the gill

Functions of parts of the gill

1. Gill rakers. These filter large particles in the water before they reach and damage the gill filaments

2. Gill bar. These provide attachment and support for the gill filaments
3. Gill filaments. These are the sites of gas exchange

Diagram



Ventilation

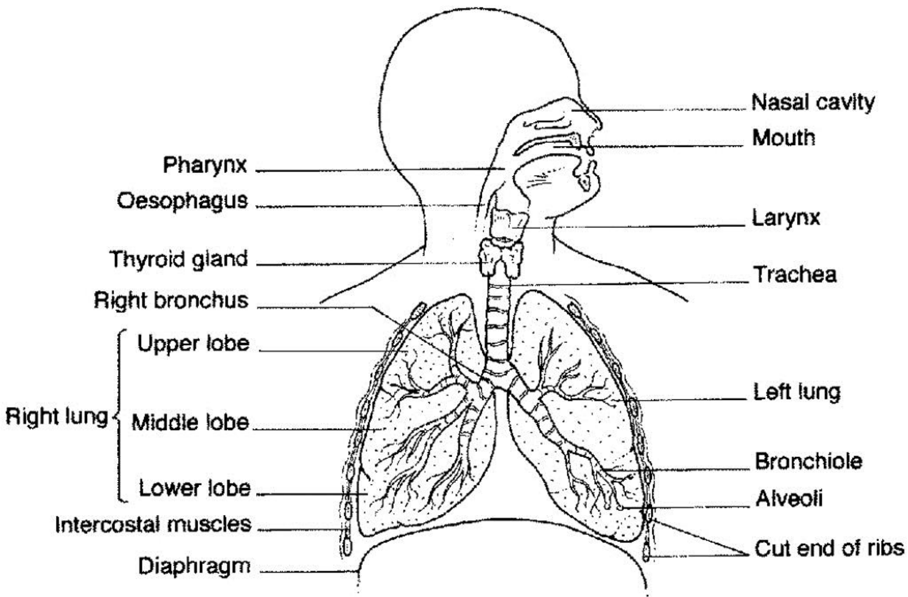
As the mouth opens, the floor of the mouth is lowered. Pressure inside the mouth is lowered and this causes water to be drawn into the bucal cavity. Meanwhile the operculum is closed, preventing water from entering or leaving through the opening.

As the mouth closes and the floor of the mouth is raised, pressure in the bucal cavity increases. Water is forced over the gills as the opercula are forced to open. As water passes over the gills, oxygen is absorbed and carbondioxide from the gills dissolves in the water.

Gaseous exchange in mammals e.g. man

The breathing system of a mammal consists of a pair of lungs which are thin walled elastic sacs lying in the thoracic cavity. The walls of the thorax consists of the ribs and the intercostal muscles while the floor consists of the diaphragm, a muscular flap of tissue between the thorax and the abdomen

Diag. main parts of the breathing system in man



Air enters the lungs through the trachea which is devided into two brochi, one to each lung. The trachea and bronchi have walls made up of rings of cartilage. Inside the lungs , each bronchus is divided into smaller tubes called bronchioles. The bronchioles terminate in saclike atria giving rise to numerous air sacs or alveoli. Each alveolus is a thin walled sac covered by numerous blood capillaries

Ventilation

Exchange of air between the lungs and the outside is made possible by changes in the volume of the thoracic cavity. This volume is altered by the movements of the intercostal muscles and the diaphragm.

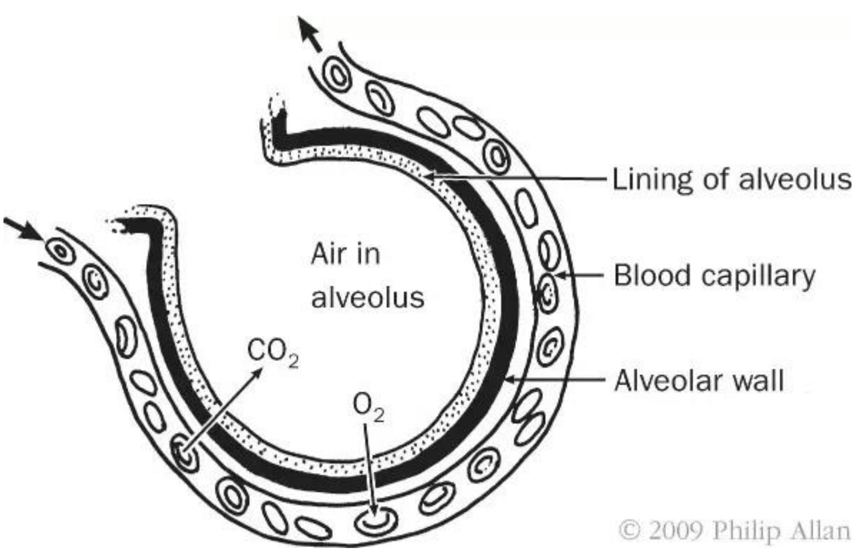
Inhalation	**Exhalation**
▪ External intercostal muscles contract and internal intercostals muscles relax.	External intercostal muscles relax and internal intercostal muscles contract
▪ This causes the rib cage to move up wards and out wards (the rib cage rises)	This causes the rib cage to move inwards and down wards (the rib cage falls)
▪ The Diaphragm contracts and flattens out.	The Diaphragm relaxes and becomes dome shaped.
▪ The volume of the chest cavity increases as the pressure is lowered.	The volume of the chest cavity decreases as the pressure increases
▪ The lungs fill with air (inflate)	The lungs deflate or expel air.

Gaseous exchange between the alveoli and the capillaries

- The walls of the alveoli and the capillaries are very thin and closely attached to each other. This makes diffusion of gases very efficient because the distance between the inside of the capillary and the inside of the alveolus is very small.
- Furthermore, the lungs have over 700 million alveoli offering a large surface area for gaseous exchange
- The walls of the alveoli are also moist, this makes oxygen dissolve easily

Blood from the tissues has a high concentration of carbondioxide and very little oxygen compared to alveolar air. The concentration gradient favours diffusion of carbondioxide into the alveolus and oxygen into the blood plasma in the capillaries. The oxygen is then picked by the haemoglobin of red blood cells and transported in combination with it as oxyhaemoglobin. Carbondioxide which is at a higher concentration in the blood is normally carried as bicarbonate ions in the plasma. This breaks down and releases carbondioxide which then diffuses into the alveolus.

Diagram



Percentage composition of inspired and expired air (% by volume)

Component	Inspired air	Expired air
Oxygen	21	16
Carbon dioxide	0.04	4
Nitrogen	79	79
Moisture	Variable	saturated

GASEOUS EXCHANGE IN PLANTS

The site of gaseous exchange in plants is mainly the stomata on the leaves and the lenticels on herbaceous stems. A few plants living in water have breathing roots too.

During day

In day light plants mainly use carbon dioxide for photosynthesis and give off oxygen. However, plant cells also respire during day hence using oxygen and giving out carbon dioxide (respiration) Photosynthesis is more active process of the two therefore uses more CO_2 than is given out during respiration and it gives out more O_2 than is used up in respiration. Plants also give off H2O (g) during respiration.

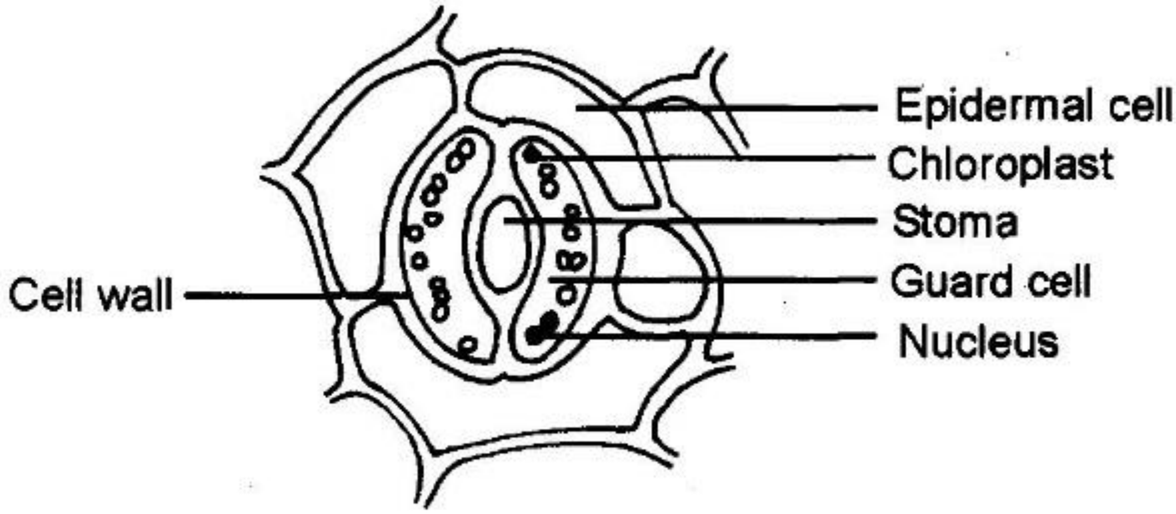
During night

In the dark photosynthesis stops but respiration continues. The plants therefore take in O_2 from its surrounding and give out carbon dioxide. The vol. of gas exchanged at night is usually very small because plants are generally less active and respire less. Most of its stomata tend to close at night. N.B. plants don't breath but gases pass into and out of them by simple diffusion. Plants don't have a breathing mechanism because they don't carry out locomotion therefore have low energy requirements, have a low metabolic rates and therefore required less O_2 don't have to keep a constant temp.

Stomata

Are tiny pore in the epidermis of foliage leaves. Each stoma is bounded by bean shaped guard cells. Guard cells differ from other epidermal cells in size, shape and in having chloroplasts.

The walls of guard cells next to the pore are thickened and inelastic are shown above. The opening and closing of stomata is controlled by its guard cells. When tugor pressure in guard cells is high, the guard cells become swollen and the stomatal pore opens. When tugor pressure is low, the guard cells become flaccid and the stomatal pore closes. Stomata generally tend to close at night and open during the day. Also tends to close during the day if conditions are unfavorable.



MECHANISM OF OPENING AND CLOSING OF STOMATA.

Day time (light)	**Night time (dark)**
1. The concentration of CO_2 is low because photosynthesis is going on.	The concentration of CO_2 is high because photosynthesis has stopped.
2. The acidity in the guard cells is low and the PH is high.	The acidity in the guard cells is high and the PH is low.
3. This favour conversion of starch to sugar.	This does favour conversion of sugar to starch.
4. H_2O then enters the guard cells by osmosis.	Water is lost from the guard cells to the surrounding.
5. the guard cells become more turgid	Guard cells become flaceid.
6. the stomata **opens**	The stomata **closes**

The Average CO_2 content of the atmosphere has been found to be fairly constant at about 0.031. 300 parts per million (ppm). It is possible to measure the CO_2 content of air accurately. The graph below shows measurements for the air of a forest over a period of 24 hours.

TISSUE RESPIRATION (CELLULAR)

This is a process by which a food substance is broken down in cells to release energy. The common food substances that are respired are carbohydrates in the form of glucose. In absence of glucose lipids can also be broken down to give energy and in times of emergencies e.g. during starvation, proteins can also be broken down to give energy. There are two forms of tissue respiration.

1. **Aerobic respiration** which is the breakdown of the food substance to release energy in presence of O_2
2. **Anaerobic** is the breakdown of food substance to release energy in absence of O_2

ANAEROBIC RESPIRATION

IN PLANTS AND FUNGI:

Yeasts are examples of organisms that leave in places where there is little or no air and have to respire anaerobically. These unicellular fungi leave in sugar containing solution such as over ripe fruit juice. Yeast respires by breaking down simple sugars to ethanol and CO_2 and some little energy is released

$$\textbf{Glucose} \longrightarrow \textbf{Ethanol + Carbon dioxide + Energy}$$

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + CO_2 + 210\ \text{k (joules)}$$

The above process is known as fermentation. The alcoholic content of beers, wines and spirits e.g.waragi, Brandy is ethanol. These drinks are made by allowing yeast to ferment in naturally occurring sugar solutions. E.g. beer from malt which comes from germinated barley

Brew	**Source**
Mwenge bigere	Ripe bananas
Malwa	Germinated millet
Omuwemba	Germinated sorghum
Kwete	Germinated millet
Wine	Grape juice

Bakers use yeast to make bread rise. The holes in the dough are formed by bubbles of CO_2 given off as the yeast respires. This makes bread more spongy and easier to digest.

IN ANIMALS

Endo parasites e.g. tape worms, respires anaerobically and most animal tissue can respire anaerobically if they need to e.g. during a sprint race-an athletes muscles use up energy so quickly that the blood system can no longer supply all the O_2 they need. For the first few seconds of the race, the muscle cells respires aerobically until the immediate supply of O_2 is used up, after that; they respire anaerobically by breaking down glucose to lactic acid

Glucose $\longrightarrow$ lactic acid + Energy.

$C_6H_{12}O_6 \longrightarrow 2(C_3H_6O_3)$ + 150 k joules

The waste product lactic acid builds in the muscles cells and since it is toxic, it must not be allowed to remain in the muscles that's why the pants after a race. By panting (Breathing quickly and deeply) we increase our O_2 supply. When this O_2 reaches the muscles cells, it oxidizes the lactic acid to energy, CO_2 and H_2O. When muscles cells are very active they incur an oxygen "debt".

An oxygen "debt" is the amount of oxygen required to break down the lactic acid which has accumulated in the respiring muscles to Carbon dioxide, water and energy

Lactic acid + O_2 $\longrightarrow$ Carbon dioxide + water +Energy

$C_3H_6O_2$ + 3O2 $\longrightarrow$ $3CO_2 + 3H_2O$ +Energy

If too much lactic acid builds up in our muscle cells one develops a muscle cramp / fatigue if one tries to persist the muscles may coarse up and one collapses from exhaustion.

OBLIGATE ANAEROBES:

They respire entirely anaerobically and they live permanently in oxygen deficient conditions such that the presence of O_2 poisons them.

FACULTATIVE ANAEROBES:

These anaerobes can respire aerobically but in limited oxygen or absence of oxygen, they respire anaerobically.

EXPERIMENTS. Describe the experiments below. Use any text book
EXP'T 1 : Does the anaerobic respiration of yeast produce $CO_{2?}$
EXP'T 2: Do green plants produce carbon dioxide during respiration
EXPT'T 3: Do germinating seeds produce heat energy?
EXP'T 4: is carbon dioxide present in the air we exhale?/To find out whether exhaled air contains carbon dioxide

EXP'T 4: is carbon dioxide present in the air we exhale?/To find out whether exhaled air contains carbon dioxide

Apparatus and materials

- Wash bottles
- Delivery tubes
- Small animal, e.g. a frog
- Lime water
- Caustic soda solution
- Wide mouthed bottle

Procedure

Set up the apparatus as shown below,
Put a frog in the wide mouthed bottle.
Place some caustic soda solution and lime water separately in the first two bottles respectively
Connect the delivery tube from bottle D to a filter pump for 30 minutes
Observe any changes in the bottles
Illustration

Observation

Lime water in wash bottle B remained clear while that in bottle D turned milky

Explanation

The caustic soda solution was used to absorb carbon dioxide from the air before reaching the animal. That is why the lime water in bottle B remained clear. The lime water in bottle D turned milky due to the carbon dioxide from the animal. Since carbon dioxide is one of the products of aerobic respiration in animals, the organism is therefore respiring anaerobically.

Conclusion

An animal gives out carbon dioxide during photosynthesis

Comprises between Aerobic and Anaerobic respiration

Similarities.

- Both release energy.
- Both take place in living organisms.
- Both require glucose as a row material.
- Both produce CO_2 except in man.

Differences

Aerobic	Anaerobic
Requires O_2 to break down glucose	doesn't require O_2 to break down glucose
More efficient & more energy is produced (38 ATP molecules)	Less efficient & less energy production (2 ATP molecules)
End product are energy, CO_2 & H_2O in both plants and animals	End products in plants are energy, ethanol & CO_2 and in animals energy and lactic acid.
There is complete oxidation of glucose to form energy, CO_2 & H_2O	Incomplete break down of glucose to intermediate compounds (lactic acid in animals and ethanol in plants)
Most common occurring in both plants & animals	Rare occurring in a few plants , fungi , & animals

What happened when a cell respires?

Glucose and other simple sugars are the most widely used respiratory materials throughout the living world. In living cells they are broken down in stages each controlled by its own enzyme. At each stage little energy is released and stored temporally in a chemical called **ATP (**Adenosine tri phosphate). **ATP** molecules consist of three phosphates groups and when a cell needs energy ATP is broken to **ADP** and energy produced.

ATP $\longrightarrow$ **ADP (Adenosine di-phosphate) + phosphate + Energy.**

ATP is reformed from ADP and a phosphates group as energy is released in the respiration process ATP provides a means of storing energy until it is required and therefore aroids wastage of energy. When a glucose a molecule is completely oxidizes in aerobic respiration about 32 molecules of ATP are formed. Each provides a small store for energy which of cells can release and use as required.

ADP(Adenosine di phosphate) + phosphate (in the presence of energy from respiration) ATP

Comparisons of respiration and photosynthesis

Respiration	**Photosynthesis**
1. Occurs in all living cells of plants and animals.	Occurs only in plants containing the green pigment chlorophyll.
2. Goes on at all times.	Only occurs in light.
3. Uses O_2 but the process can occur without this gas.	CO_2 is needed as a raw material.
4. CO_2 is produced.	O_2 is produced.
5. H_2O is produced	More H_2O is used up than is produced. (They is a net gain of H_2O).
6. Energy is produced.	Energy of sunlight is observed by the chlorophyll and stored in complex organic molecules.
7. Proceeds at a much slower rate than photosynthesis in green plants in terms of gaseous exchange.	Produced at a much faster rate than respiration in green plants in terms of gaseous exchange.

Obligate anaerobes are those that respire anaerobically and are killed by even an O_2 trace e.g. certain anaerobic bacteria.

Facilitates anaerobes have the ability of facilitate to respires anaerobically but are able respires aerobically when the opportunity arises e.g. yeast.