RESPIRATION

INTRODUCTION

The attainment of multicellular structure is very well foreshadowed by the Metazoa in which the limitations of size are removed. **In Metazoa special regions of the body are set aside for dealing with different functions**. A special region of body is set aside for dealing with **respiration**.

Smaller Metazoa are aquatic, their large surface provides an adequate area for interchange of gases. The larger Metazoa have a relatively **smaller surface area** and they may have an external covering, hence, they form **respiratory organs**.

These organs differ in different animals *i.e.*, with the advent of multicellularity.

These organs of respiration may be covered or lined by **ectoderm** *e.g.*,

i) **Gills** of Crustaceans and Annelids

ii) **External Gills** of Tadpole

iii) **Lungs** of Snails

or they may be covered by **endoderm** *e.g.*,

i) **Gills** of Fish &

ii) **Lungs** of Vertebrates.

RESPIRATION

Respiration is a **catabolic process** which involves **exchange** of environmental **Oxygen** and body's **CO_2** through a liquid medium, either in the presence or absence of a respiratory pigment, to utilize the O_2 for the oxidation of glucose in the mitochondria to produce the energy. Some of which is stored in the high energy bonds (~) of ATP molecules as **biological useful energy**. So respiration is a **physico-chemical** process.

✓ **Respiration is found in all animals, but all animals do not breathe**.

IMPORTANCE

1. Importance of respiration lies in the fact that **neurons die if deprived of O_2** simply for few minutes.
2. In desert dwelling animals, **respiration provides metabolic water** *e.g.*, Kangaroo rats, Camel etc.

✓ **Kangaroo rat never drinks water throughout its life. It mainly feeds on protenacious food which provides good quantity of metabolic water throughout respiration.**

3. The various **metabolic processes** carried out by an organism *e.g.*, **movements**, **growth** and **reproduction requires the expenditure of energy** *i.e.*, all living cells need energy for carrying on their functions. In animals the source of energy is the food (carbohydrates, lipids and proteins) which they eat and is brought to the cells by the blood from the alimentary canal or liver. The **molecules of food hold energy in their chemical bonds**. Their bond energy is released by oxidation in the cells. In oxidation, usually oxygen is used, carbon dioxide and water are produced as byproducts, and energy is released. The process occurs in many steps, the net equation being:

$C_6H_{12}O_6$ +	$6O_2$	$\longrightarrow$	$6CO_2$	+	$6H_2O$	+	**Energy**
Glucose	Oxygen		Carbondioxide		Water		Stored in ATP
			(Eliminated)		(Reused)		(Energy used in life activities)

4. **Carbon dioxide** is poisonous and harmful for the cells if accumulates, so equally important is the **expelling of Carbon dioxide**. **Water** is useful and **retained** in the cells. **Energy** released in oxidation is **stored** in high energy bonds of **ATP** molecules. These bonds are later broken by enzymatic hydrolysis and the energy so set free is used by the cells in their activities. The energy obtained from the ATP molecules is called biologically useful energy because it drives the life processes. So there is an urgent need of respiration, which will ensure a continuous supply of Oxygen. The multistep reaction may be briefly expressed as under:

The process that generally involves:

(i) **Intake** of molecular oxygen from the environment,

(ii) **Oxidation** of food with the incoming oxygen,

(iii) **Elimination** of carbon dioxide produced in oxidation,

(iv) **Release** of energy in small doses during oxidation, and

(v) **Conservation** of energy so released in biologically useful forms, such as ATP,

is known as **respiration.** The term respiration is derived from Latin word which means "**to breath**" or "**exhale**".

Respiration, a catabolic process, may be briefly defined as the **exchange of environmental Oxygen with the Carbon-dioxide produced in the cells during oxidation** at a **moist surface** to utilize the oxygen for the **oxidation of Glucose** to produce the energy, some of which is stored in the high energy bonds of ATP molecules as biological useful energy. Robert Boyle and Robert Hook (1600) first explained respiration. Lavoisier (1743-1794) explained the importance of Oxygen in respiration.

Respiratory Substrate: Compounds being oxidized in respiration.

Respiratory Surface: Surface at which exchange of gases occur.

Respiratory Mediums: Source of O_2 like water and air.

RESPIRATORY SURFACE

The surface at which exchange of gases occurs is termed **respiratory surface.** This surface must have **enough area of gas exchange** to meet the metabolic needs of the organism. For the nonstop release of energy (respiration), the cells need uninterrupted supply of oxygen and constant removal of carbon dioxide. A steady supply of oxygen is absolutely essential for certain cells. A nerve cell dies if deprived of oxygen for a few minutes. This is why even a brief choking or strangulation can damage the brain. This indicates the necessity of oxygen or respiration for life.

RESPIRATORY MEDIUMS

OXYGEN SUPPLY

Most of the earth's oxygen occurs in the air, but some is dissolved in water. Thus, air or water may serve as the source of oxygen for the animals. The source of oxygen is called **respiratory medium. The respiratory medium supplies oxygen to the body at the body's respiratory surface**. The latter may be the general body surface or some specialized area such as lung or gill. Most of the animal's cells lie some distance from the respiratory surface, and obtain oxygen from the tissue fluid, which bathes all the cells. Blood brings oxygen from the respiratory surface to the tissue fluid and carries CO_2 from the tissue fluid in the reverse direction.

Exchange of gases across a respiratory membrane occurs by **diffusion**, and diffusion can distribute substances over a short distance only, about 0.5 mm. Therefore, the animals having cells more distant than 0.5 mm. from the respiratory surface require circulatory system to transport the gases between the respiratory surface and the tissue fluid present around the cells.

CHARACTERISTICS OF RESPIRATORY SURFACE

As the external respiration depends upon the **principle of diffusion** so for the **efficient** gaseous exchange, respiratory surface must have the following **characteristics**:

1. It must be **thin**.
2. It must be **permeable** to the respiratory gases (O_2 + CO_2).
3. It must be **moist** either with water or mucous.
4. It must be highly **vascular**.
5. It must be in direct or indirect **contact with source** of O_2.
6. Presence of respiratory **pigment** in many animals to increase the O_2 and CO_2 carrying capacity of the blood.

TYPES OF RESPIRATION

- **Respiration**
  - Aerobic
    - Types
      - Direct Respiration
      - Indirect Respiration
    - Phases
      - External Respiration
      - Internal Respiration
      - Cell Respiration
  - Anaerobic

AEROBIC AND ANAEROBIC RESPIRATION

(a) **AEROBIC RESPIRATION**: In most animals and plants, respiration involves **use of molecular oxygen** & **release of carbon dioxide** simultaneously. Such a respiration is called aerobic respiration. The organisms which carry on aerobic respiration are termed **aerobes**. It is active efficient process.

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{in mitochondria}} 6CO_2 + 6H_2O + 288 \text{ kJ Energy}$$

(2) **ANAEROBIC RESPIRATION**: It was first reported by KOSTYCHEV. In some organisms, respiration may or may not produce carbon dioxide but **does not utilize molecular oxygen**. For example, **yeasts** oxidize glucose to ethanol (ethyl alcohol) and carbon dioxide without utilizing oxygen:

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + \text{Energy}$$

In certain **bacteria** and **parasitic worms** (*Ascaris*, Tapeworm), glucose is metabolized to lactic acid without the use of oxygen and without the formation of carbon dioxide:

$$C_6H_{12}O_6 \longrightarrow 2CH_5COCOOH + \text{Energy}$$

The process of releasing energy without the use of oxygen is called anaerobic respiration, or anaerobic metabolism. It is also termed **fermentation**. Fermentation yields only about 5% of the energy available in glucose, and is, thus, a wasteful process. The organisms which carry on anaerobic respiration are termed **anaerobes**.

The aerobes also carry on anaerobic metabolism in certain tissues such as skeletal muscles. These muscles do not get sufficient oxygen, and anaerobically metabolise glucose to lactic acid during vigorous movements. Accumulation of lactic acid in muscles causes fatigue. Lactic acid is carried by the blood from the muscles to the liver, where part of it is oxidized aerobically and the rest changed into glycogen for reuse in oxidation. Certain cells, such as mammalian red blood corpuscles, lack mitochondria for aerobic respiration and must depend on anaerobic metabolism.

DIRECT AND INDIRECT RESPIRATION

Aerobic respiration is of two main types: direct and indirect

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. Exchange of gases occurs on the principle of diffusion. It is found in aerobic bacteria, protests, plants, sponges, coelenterates, flatworms, roundworms and most arthropods. In these organisms, there is direct contact between cells of the body and the surrounding air or water.

Protists: *Amoeba proteus* is about 0.25 mm. wide and has a large surface area to volume ratio. Diffusion of gases occurs over the entire surface via cell membrane, and is enough to fulfill its metabolic requirements.

Coelenterates: In *Hydra* and *Obelia*, practically all cells are in contact with the surrounding water. Each cell can exchange gases sufficient for its own needs through the cell membrane adjacent to water.

Flatworms: Planaria can also exchange gases sufficient for its needs by diffusion over its body surface. This is facilitated by its very thin body which increases the surface area to volume ratio.

Indirect Respiration

In this type of respiration, there is **no direct contact between the body cells and the surrounding air or water.** The **body wall is thick** to prevent the loss of water by evaporation, so the direct exchange of gases is impossible. It is found in larger and complex form of animals. These organisms have some **specialized structures** for gaseous exchange called respiratory organs. These special respiratory organs include **skin, buccopharyngeal lining, gills** and **lungs**, and need the help of **blood**. The respiration in the skin, buccopharyngeal lining, gills and lungs is respectively called cutaneous, buccppharyngeal, branchial and pulmonary respiration. Cutaneous respiration takes place in annelids, some crustaceans and amphibians. 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. Branchial respiration is found in many annelids, most crustaceans and mollusks, some insect larvae, echinoderms, all fishes and some amphibians. It occurs in water only. **Pulmonary respiration** is founds in snails, some amphaibians and in all reptiles, birds and mammals.

PHASES OF RESPIRATION

TWO PHASES OF AEROBIC RESPIRATION

1. **External Respiration**: Breathing or Ventilation.
2. **Internal Respiration**: Tissue respiration.

EXTERNAL AND INTERNAL RESPIRATION

The indirect respiration has two phases: external respiration and internal respiration. These are preceded by a preliminary phase called breathing or ventilation.

Breathing: Breathing refers to the movements that sends fresh air or water to the respiratory organs and removes foul air or water from them. Ventilation is necessary because gas exchange depends on diffusion and the greater the concentration gradient of gases across the respirator surface, the faster the gases will diffuse between the reparatory medium and the blood.

External respiration: External respiration is the **intake of oxygen** by the blood from water or air in the respiratory organs and **elimination of carbon dioxide**.

Internal respiration: Internal respiration involves **four processes**:

(i) **Uptake of oxygen** by tissues cells from the blood via tissue fluid.

(ii) **Oxidation of food** in the tissue cells by the action of oxidizing enzymes, producing carbon dioxide, water and energy.

(iii) **Storage of energy** from oxidation in the phosphate bonds of ATP.

(iv) **Release of carbon dioxide** by tissue cells into the blood via tissue fluid.

The enzymatic oxidation of food in the cells is often called cell respiration.

GAS EXCHANGE

MECHANISM

- ✓ The **exchange of gases** (O_2 and CO_2) in the respiratory organs and the tissues takes place according to the **laws of gases**, and is, thus, a physical rather than a biological process.
- ✓ Gas exchange occurs partly by **diffusion** and partly by **facilitated diffusion**. The facilitated diffusion uses a carrier protein, namely, a **cytochrome**, which speeds up diffusion, allowing the blood to take up oxygen faster. Diffusion is the net flow of a substance from a region of higher concentration (or higher partial pressure or K. E.) to a region of lower concentration (or lower partial pressure or lower K. E.). **The diffusion is directly proportional to**:

(i) **Partial pressure gradient** (difference) of gases on the two sides of a membrane between them;

(ii) **Thinness** of the membrane,

(iii) **Surface area** of the membrane, and

(iv) **Permeability** of the membrane.

Moisture is also necessary because O_2 and CO_2 are more easily exchanged in cells when in a liquid medium.

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 divide 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.

The partial pressure (concentration) of oxygen (P_{O2}) is higher in the water/air drawn to the gills/lungs than in the venous blood flowing in the capillaries of the respiratory organs. Hence, oxygen diffuses from the water/air into venous blood. In the case of lungs, oxygen of the air dissolves in the mucus that lines the alveoli before diffusing into the blood. The partial pressure (concentration) of carbon dioxide (P_{CO2}) is higher in the blood flowing in the capillaries of the respiratory organs than in the water/air drawn to the gills/lungs. With the result, carbon dioxide diffuses from the blood into the water/air. Diffusion of both the gases occurs simultaneously.

The gases behave in a similar manner in their exchange between the blood and the tissue cells. Here, the concentration of oxygen is higher in the blood than in the tissue cells, and the concentration of carbon dioxide is greater in the tissue cells than in the blood. Hence, oxygen diffuses from the blood into the tissue cells, and carbon dioxide diffuses from the tissue cells into the blood. Diffusion of both the gases takes place simultaneously, and via tissue fluid. Oxygen is utilized in the cells in oxidative reactions, producing carbon dioxide, and this maintains oxygen gradient between the blood and the cells, and carbon dioxide gradient in the reverse direction.

ADAPTATION FOR GAS EXCHANGE

For **efficient gas exchange**, the **respiratory surfaces have large area and are thin, moist, highly vascular and permeable**. Water or air is **circulated** past the respiratory surfaces. This keeps the Po_2 high and Pco_2 low into water or air in contact with respiratory surface to maximize the pressure gradient. Many animals have developed special respiratory pigments which greatly increase the capacity of the blood to carry oxygen and carbon dioxide. The common respiratory pigments are haemocyanin found in the plasma in the crustaceans and mollusks, and haemoglobin found in the red blood cell in the vertebrates, and in the annelids in the plasma.

TABLE 1: DIFFERENCES BETWEEN AEROBIC AND ANAEROBIC RESPIRATION

Aerobic Metabolism	Anaerobic Metabolism
1. It uses molecular O_2.	1. It does not use molecular O_2.
2. It always releases CO_2.	2. It may or may not release CO_2.
3. It produces H_2O.	3. It does not produce H_2O.
4. It involves exchange of gases between organisms and environment.	4. Exchange of gases does not occur as oxygen is not absorbed by respiring cells.
5. Respiratory substrate is completely broken down.	5. Respiratory substrate is incompletely broken down.
6. It releases entire energy available in glucose as the latter is fully oxidised.	6. It releases only 5% of energy available in glucose as the latter is not fully oxidised.
7. It contains 5 steps: glycolysis, pyruvate oxidation, TCA cycle, ETS (Electron Transport System) and chemiosmotic ATP synthesis.	7. It contains 2 steps: glycolysis and incomplete breakdown of pyruvate.
8. It yields inorganic end products (CO_2 and H_2O) only. No organic end products are formed.	8. It yields one or more organic end products (Lactic acid and Ethyl alcohol) with or without an inorganic one.
9. It produces CO_2.	9. CO_2 may or may not be produced. Wherever formed, it is produced in comparatively smaller quantity.
10. Metabolic water is formed as one of the end products.	10. Metabolic water is not produced.
11. It occurs partly in the cytoplasm and partly in the mitochondria	11. It occurs in cytoplasm only, Mitochondria are not required.
12. 38 molecules of ATP are released.	12. 2 molecules of ATP are released
13. It releases 686 kcal or 2870 kJ of energy per mole of glucose.	13. It produces 36 – 50 kcal (150 – 210 kJ) of energy per mole of glucose.
14. It can occur indefinitely.	14. It occurs continuously only in some microorganisms. In others it takes place only as a stop-gap arrangement during periods of oxygen deficiency.
15. Electron Transport Chain is required.	15. An Electron Transport Chain or System is not required.
16. Oxygen is ultimate acceptor of electrons and protons.	16. Pyruvate or its derivative is the acceptor of electrons and protons.
17. It is found in the majority of animals and plants.	17. It is found in a few lower organisms such as yeasts, some bacteria, germinating seeds, parasitic worms (*Ascaris*, *Taenia*), tissue and cells of higher organisms like skeletal muscles and RBCs.

TABLE 2: DIFFERENCES BETWEEN EXTERNAL AND INTERNAL RESPIRATION

Particulars	External Respiration (Breathing)	Internal Respiration
1. Site of occurrence	At the respiratory surface. It is a preliminary step for respiration.	At the cellular level.
2. Process	Physical process; Extracellular.	Biochemical process; Intracellular.
3. Involves	Inspiration of fresh air and expiration of foul air.	Exchange of gases and oxidation of food.
4. Exchange of gases	Oxygen of air or water and carbon dioxide of blood.	Oxygen of blood and carbon dioxide of tissue cells.
5. Nature	Physical process.	Physico-chemical process.
6. Mechanism	Varies in different animals.	Similar in all animals.
7. Energy	Food is not oxidised, so no energy is produced.	Food is oxidised in the mitochondria and energy is released.
8. Enzymes	Enzymes are not involved.	A large number of enzymes are involved.
9. Occurrence	Confined to certain organs only.	Occurs in all cells of the body.

TABLE 3: DIFFERENCES BETWEEN RESPIRATION AND COMBUSTION

Respiration	Combustion (Burning)
1. It is a multi-step reaction	1. It is a single step reaction.
2. Biochemical phenomenon, taking place in steps in a controlled manner.	2. Physico-chemical phenomenon that takes place spontaneously.
3. Chemical bonds break one after another, releasing energy gradually.	3. Many chemical bonds break simultaneously, releasing a large amount of energy at a time.
4. Takes place inside the cells (Intracellular process).	4. It is not cellular.
5. Temperature remains low (controlled) due to liberation of heat in very small packets.	5. Temperature rises considerably.
6. Most of the energy is entrapped in new chemical bonds (ATP) so that little is lost as heat.	6. Most of the energy dissipates away as heat. No ATP is formed.
7. About 50% of the energy is stored.	7. Energy is not stored.
8. Several intermediate compounds are produced	8. No intermediate compounds are produced
9. Each step of respiration is catalyzed by an enzyme.	9. No enzymes are involved.
10. Occurs in a controlled manner (Biologically controlled).	10. An uncontrolled process.
11. Light is not an accompaniment of respiration, though certain organisms can produce light.	11. Light is often emitted.
12. Oxygen is involved in terminal oxidation or oxidation of reduced coenzymes.	12. Oxygen is used in direct oxidation.

TABLE 4: DIFFERENCES BETWEEN PHOTOSYNTHESIS AND RESPIRATION

Photosynthesis	Respiration
1. It is an anabolic process resulting in the synthesis of organic molecules (glucose) from simple inorganic molecules (CO_2 and water).	1. It is a catabolic process resulting in the breakdown of organic molecules (mainly glucose) into simpler inorganic ones (CO_2 and water).
2. It uses CO_2 and H_2O.	2. It releases CO_2 and H_2O.
3. Results in the increase in weight	3. Results in decrease in weight.
4. It is an endergonic process since it stores chemical energy in the bonds of organic compounds.	4. It is exergonic process as it releases chemical energy of the bonds in organic compounds.
5. It takes place during sunlight only.	5. It takes place all the time (day and night).
6. It is confined to the green parts of the plants only.	6. It occurs in the cells of all the parts of the organism.
7. It occurs in plastids.	7. It occurs partly in the cytoplasm and partly in the mitochondria.
8. Plants can live for many days without photosynthesis.	8. Organisms soon die without respiration.

TABLE 5: DIFFERENCES BETWEEN GLYCOLYSIS AND KREBS CYCLE

Glycolysis (EMP Pathway)	Kreb's Cycle (TCA or Citric Acid Cycle)
1. It is the first step of cellular respiration.	1. It is the second step of cellular respiration.
2. Its substrate is glucose.	2. Its substrate is Acetyl CoA.
3. It takes place in cytoplasm.	3. It takes place in the matrix of mitochondria (exception aerobic procaryotes).
4. It is a common step in both aerobic as well as anaerobic modes of respiration.	4. It occurs in aerobic respiration only.
5. It consists of 9 steps.	5. It consists of 8 steps.
6. It is a linear or straight pathway	6. It is a cyclic pathway.
7. It oxidises glucose partly, producing two molecules of pyruvate.	7. Activated acetate of acetyl Coenzyme A is completely broken down to inorganic state.
8. It requires priming reaction.	8. It requires a link reaction or gateway step.
9. It consumes 2 ATP molecules.	9. It does not consume ATP.
10. It produces 4 ATP molecules from 1 glucose molecule through substrate level phosphorylation.	10. It generates 2 GTP/ITP/ATP (Guanosine / Inosine / Adenosine TriPhosphate) molecules from 2 acetyl coenzyme A molecules through substrate level phosphorylation.
11. It yields 2 NADH ($+H^+$) per glucose molecule.	11. It yields 6 NADH ($+H^+$) molecules and 2 $FADH_2$ molecules from 2 acetyl coenzyme A molecules. 2 NADH ($+H^+$) are additionally formed through link reaction.
12. It is not linked to Electron Transport.	12. It is linked to Electron Transport.
13. It does not produce CO_2.	13. It produces CO_2.
14. All enzymes catalysing glycolytic reactions are dissolved in cytosol.	14. Two enzymes of Krebs cycle reactions are located in the inner mitochondrial membrane, all others are dissolved in matrix.

TABLE 6: INPUT AND OUTPUT CHART OF GLYCOLYSIS

S. No.	Input (Glycolysis)	Output (Glycolysis)
1.	Glucose (6-C) – 1 molecule	Pyruvate (3-C) – 2 molecules
2.	2 ATP	2 ADP
3.	4 ADP + 2 Pi	4 ATP + $2H_2O$
4.	2 NAD^+	2 NADH ($+H^+$)
Net output		**2 Pyruvate + 2 ATP + 2 NADH ($+H^+$)**

TABLE 7: ENERGY CHART OF AEROBIC RESPIRATION

Step	Products	ATP Equivalents
	(i) 4 ATP minus 2 ATP	2 ATP
	(ii) 2 NADH ($+H^+$)	6 ATP
2. Gateway step (Pyruvate oxidation)	2 NADH ($+H^+$)	6 ATP
	(i) 2 GTP	2 ATP
	(ii) 6 NADH ($+H^+$)	18 ATP
	(iii) 2 $FADH_2$	4 ATP
One Glucose Molecule		**= 38 ATP**

TABLE 8: ATP FORMED FROM ONE GLUCOSE MOLECULE

Process	Reduced Carriers	Hydrogen Produced	ATP Formed Per Carrier	ATP Formed Chemiosmotically	ATP Formed Directly
1. Glycolysis	2 NADH	2 H^+	3	6 ATP	2 ATP
2. Pyruvate Oxidation	2 NADH	2 H^+	3	6 ATP	
	6 NADH	6 H^+	3	18 ATP	2 GTP
	2 $FADH_2$		2	4 ATP	
TOTAL				**34 ATP**	**4 ATP**
GRAND TOTAL				**38 ATP**	

TABLE 9: RESPIRATORY PIGMENTS AND THEIR DISTRIBUTION

Respiratory Pigment	Location	Metallic group	Colour		Found in
			Oxygenated	Deoxygenated	
1. Haemoglobin	RBCs, in blood plasma of earthworm	Iron	Red	Purplish red	All vertebrates, Annelids
2. Haemocyanin	Plasma	Copper	Blue	Colourless	Molluscs and Arthropods
3. Haemoerythrin	Blood corpuscles	Iron	Red	Colourless	Some Annelids
4. Chlorocruorin	Plasma	Copper	Green	Green	Some Annelids
5. Pinnaglobin	Plasma	Manganese	Brown	Brown	Some Annelids

Conclusion

Animals have evolved a number of ways to deal with the problem of obtaining a rate of gas exchange proportional to their needs: increased surface area, ventilatory mechanisms to circulate air or water, increased vascularization and the utilization of various pigments involved in the transport of Oxygen and Carbon-dioxide in bloods and body fluids.

Respiratory surfaces all accomplish the same thing; they provide an extensive gas exchange surface in contact with the surrounding medium which is either water or air.

Within the surface of the respiratory organ the exchange is governed by diffusion in all animals. If the animal possesses a circulation, the gases must reach the blood by diffusion and in animals without a circulation they must pass into all tissues by this process.