SECTION

3

# DIFFUSION AND OSMOSIS

# PROCESSES FOR LIVING

## Essentials for Survival

## INTRODUCTION

Hello, students! Welcome to the fascinating world of substance movement! In both living organisms and the non-living environment, captivating phenomena known as diffusion and osmosis exist. This process involves the spontaneous movement of particles, whether they are gases, liquids, or solids. From the complex biological processes within our bodies to the dynamic interactions occurring in the surrounding world, the appreciation of substance movement in biotic and abiotic media reveals a deeper understanding of our universe's fundamental principles. In this section we will look at identification of real-life examples of diffusion and osmosis explain how they are relevant to those situations as well as conduct a simple experiment to demonstrate diffusion as well as osmosis and interpret the results. So, let us embark on a journey to explore the captivating world of diffusion and osmosis and their significance in both living and non-living systems.

**At the end of this section, you will be able to:**

- Appreciate the movement of substances in biotic and abiotic media.
- Design, model, and explain the process of osmosis and indicate its application in everyday life.

**KEY IDEAS**

- **Diffusion** is the process of particles or molecules spreading out or dispersing from an area of high concentration to an area of low concentration. The movement of the particles is spontaneous, unpredictable, and irregular.
- **Active transport** is a process that happens inside living cells to move substances from an area of lower concentration to an area of higher concentration. It is like going against the flow.
- **Osmosis** involves the movement of water (solvent) molecules from where there is more water (dilute solution) across a selectively permeable membrane to where there are less water molecules (concentrated solution).

- **A dilute solution** contains more water molecules (solvent) compared with the solute molecules, while a **concentrated solution** has more solute molecules compared with solvent molecules.
- Osmosis occurs in both plant and animal cells as well as in non-living tissues.
- A **selectively permeable membrane** allows some substances to pass through and prevents others from passing through it.

# CONCEPTS OF DIFFUSION AND ITS APPLICATION IN LIFE

## Concepts of Diffusion

Diffusion refers to the movement of molecules from an area of high concentration to an area of low concentration until the molecules are evenly distributed. The driving force behind diffusion is the concentration gradient, which is the difference in concentration between two regions. Diffusion always tends to equalise the concentration gradient leading to a uniform distribution of molecules and equal concentration throughout space or solution.

### Examples of Diffusion in Living and Non-Living Cells:

1. **Diffusion in Living Cells**
   a. Oxygen diffuses from areas of high concentration (such as the blood) into cells where its concentration is lower. This process is crucial for cellular respiration, where cells use oxygen to produce energy.
   b. After cellular respiration, carbon dioxide, a waste product, accumulates in cells and diffuses out into the blood, where its concentration is lower. This diffusion process helps to remove carbon dioxide from the cells and transport it to the lungs for exhalation.
   c. Glucose, a primary energy source, diffuses into cells from areas of higher concentration (like the blood) to areas of lower concentration (inside the cells). This diffusion is often facilitated by specific transport proteins in the cell membrane, ensuring cells receive the glucose needed for energy production through glycolysis and other metabolic pathways.

Below is a link to a video on diffusion in living cells. Click on the link to watch it.
https://www.youtube.com/watch?v=TRP3jCmkYiM

**2. Diffusion in Non-Living Cells**

a. If you leave a cup of hot chocolate on the table, you will notice that the steam rises and the aroma spreads in the air. This is because the hot chocolate particles move through diffusion, spreading out and mixing with the air particles.

b. When you add a spoonful of sugar to a cup of tea or coffee without stirring it, the sugar particles dissolve and spread throughout the liquid. This happens because of diffusion, where the sugar particles move from a higher concentration (the spoonful) to a lower concentration (the rest of the liquid).

The examples above show how diffusion is a natural process that happens in both living and non-living cells, allowing particles to spread out and fill the available space.

## Factors that Affect Diffusion

Dear learner, click on the links below to watch the videos and describe your observations.

https://www.youtube.com/watch?v=E30DSfmAW4s

https://www.youtube.com/watch?v=lxHMJaXOzP4

## Activity 3.1

Describe and explain how each of the following factors affects the rate of diffusion.

1. Concentration gradient
2. Temperature
3. Particle size/molecular weight
4. Nature of media through which the diffusion occurs.

## Activity 3.2: Demonstrating the spread of permanganate ions in solution

**Aim:** The purpose of this demonstration is to show how particles move from an area of high concentration to an area of low concentration; the process of diffusion.

**Materials needed:** Beaker, water, potassium permanganate crystal and spatula.

### Procedure

1. Fill the beaker with water.
2. Put a piece of potassium permanganate crystal at the bottom of the beaker containing water using a spatula. Be careful so that the water is not overly disturbed and that the crystal is positioned at the bottom of the beaker without much mixing.
3. Observe what happens over a few minutes. Describe and explain your observations. Solutions can be found in Annex 1.
4. Extension task: Repeat this experiment with colder water, what do you predict will happen? Conduct the experiment to test your hypothesis.

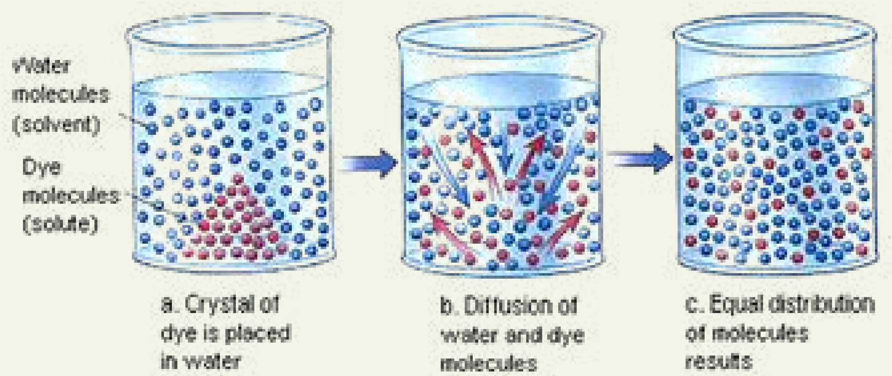


**Fig. 3.1:** Process of diffusion using potassium permanganate crystal.

*The video link below will give you a better understanding:*

https://www.youtube.com/watch?v=mNlFmvx8o7Y

## Activity 3.3: Demonstration of diffusion in gases using perfume

**Aim:** To investigate the diffusion of perfume molecules through air.

**Material needed:** A bottle of inexpensive perfume.

**Procedure:**

1. Pour a small volume of perfume onto a piece of tissue and leave it in one corner of the classroom **or** open a bottle of perfume and leave it in a corner of the classroom.

   ***Note: Spraying is not suitable for demonstrating the effect of diffusion***.

2. Raise your hands when you can smell the perfume.
3. Describe and explain how the location of the learner and the time taken to smell the perfume are related. Find solutions in Annex 1.

**Fig. 3.2:** Demonstration of diffusion by students

## Application of Diffusion in Everyday Life

Now learners, observe the following everyday activities and point out those you are very familiar with:

**Perfume/Cologne:** When you spray perfume or cologne onto the skin, the scent particles evaporate from the skin and diffuse through the air spreading from an area of high concentration (your skin) to an area of low concentration (the surrounding space).

**Cooking:** During cooking, food particles diffuse through the kitchen and sometimes beyond, allowing you to smell the food even if you are not standing directly over the stove. The food particles' movement in the air gives the food its aroma.

**Room Fresheners:** Air fresheners or diffusers release fragrance into the air. The fragrance molecules disperse and diffuse throughout the room, creating a pleasant scent.

**Tea/Coffee Brewing:** When you place a tea bag or coffee grounds in hot water, the flavour compounds diffuse from the concentrated source into the surrounding liquid resulting in a flavoured beverage.

**Oxygen and Carbon Dioxide Exchange**: In the human body, diffusion is vital for gas exchange in the lungs. Oxygen from the inhaled air diffuses from the lungs into the bloodstream, while Carbon Dioxide diffuses into the lungs to exhale.

## EXTENDED READING

Access the link below for an example of diffusion.

https://www.youtube.com/watch?v=SWByFMo32Qg

# OSMOSIS AND ITS APPLICATION IN OUR DAILY LIFE

Hello learner, we hope you enjoyed the demonstration about diffusion in your previous lesson. You are going to experience another interesting phenomenon which also talks about movement of substances both in living and non-living things. This process is osmosis. Without osmosis many biological systems may not function. For example; plants will find it difficult to absorb water through their root hairs and may eventually die.

Osmosis is defined as the process by which solvent (water) molecules move from a dilute solution to a concentrated solution across a selectively permeable membrane. In effect, there is a net movement of water molecules across a selectively permeable membrane from an area of high concentration to an area of low concentration (of the water molecules). The selectively permeable membrane could be a living or non-living tissue.

Osmosis does not require energy from the cell to occur. It takes place naturally to ensure that concentration of water molecules on both sides of the selectively permeable membrane is equal.

The direction and rate of osmosis depends on the relative concentration of solutes on either side of the membrane.

Several factors affect the rate of osmosis. Notable amongst them are concentration gradient, temperature (greater temperature leads to a faster rate of osmosis) and presence of selectively permeable membrane.

Now learner, observe the illustration in Fig 1 closely and carry out the tasks in Activity 1 alone or with your friends.

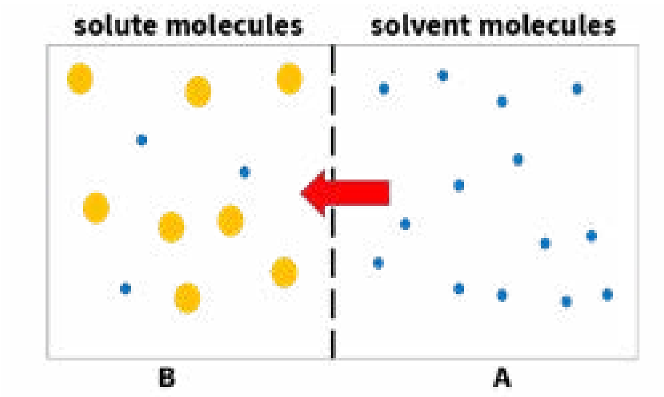


**Fig 3.3:** Illustration of Osmosis

## Activity 3.4: Osmosis at home.

**1.** Name a common household substance that contains *solvent* molecules.

**2.** Name a common household substance that contains *solute* molecules.

**3.** (a) From the illustration, which molecules are moving?

(b ) In which direction are the molecules moving?

**4.** Describe the solutions A and B.

**5.** What process is causing the molecules identified in 3(i) to move?

## Activity 3.5: Quick or slow swell.

Place a small handful of raisins or any dried fruits into a clear cup of water and take a photograph of them. Leave them for 24 hours and then take a new photograph.

Compare the appearance of the raisins before and after the experiment. Write a brief explanation of your observations.

Good, I believe you have got a clear idea of osmosis.

## Activity 3.6: Movement of molecules.

Research on YouTube to give you more insight into osmosis with respect to movement of molecules.

**1.** https://www.youtube.com/watch?app=desktop&v=sUpFhbHo9lQ

**2.** https://www.youtube.com/watch?v=qGALyEW4ZFY

**3.** https://www.youtube.com/watch?v=30yV3RaU03g

1 2 3

## Activity 3.7: Investigating osmosis in model cells with different internal water concentrations.

**Aim:** To investigate the process of osmosis on model cells with different internal water concentrations immersed in pure water/distilled water.

***Note*: *The selectively permeable membrane used here as model cell is the Visking tubing.***

**Materials needed:** 4 beakers/transparent containers, sugar/sucrose solution of concentrations 5%, 10% and 15% (weight by volume), water, Visking tubing, scissors, funnel, measuring tape, string and a ruler.

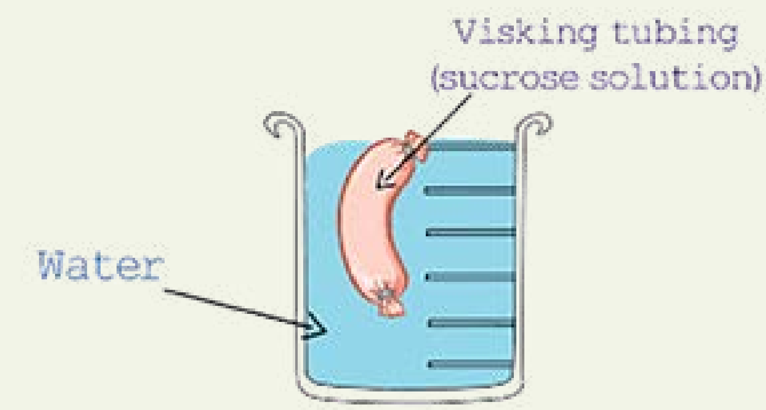


**Fig (a):** Investigating osmosis in a model cell using Visking tubing.

**Procedure:**

1. Fill each beaker/transparent container with pure water almost to the brim.
2. Cut equal lengths (12cm) of Visking tubing.
3. Tie one end of each piece of Visking tubing using string.
4. With the help of a funnel, pour pure/distilled water into the first piece of tubing and tie the other end.
5. Measure the circumference of the filled tubing using more string and the ruler and place the model into one of the beakers/transparent containers.
6. In the same way fill the next piece of Visking tubing with 5% sucrose solution and place it in beaker 2.
7. Repeat for 10% sugar/sucrose and 15% sugar/sucrose solution and place them into beaker/transparent containers 3 and 4 respectively.

8. Leave the experiment for 24 hours and measure again the circumference of the model cells.
9. Observe how the model cell feels in comparison to the beginning of the experiment.
10. Record your results in the table given.

***Note**: The model cells contain different sucrose solutions and therefore different water concentrations. 0% sucrose has the highest water concentration, and 15% sucrose has the lowest water concentration. Water can move freely into or out of the Visking tubing but sucrose cannot.*

Good. Now input your results into Table 3.1.

**Observation/Results:**

**Table 3.1**

| Beaker | Visking tubing containing | Circumference at start | Circumference after 24 hours | Firmness of model cell |
|---|---|---|---|---|
| 1 | Water | | | |
| 2 | 5% sucrose | | | |
| 3 | 10% sucrose | | | |
| 4 | 15% sucrose | | | |

**Explanation:** Explain your observation from the results obtained above.

Let's proceed to the next activity.

## Activity 3.8: Investigating osmosis in plant/living tissues.

**Aim:** To investigate osmosis in plant tissues.

**Materials you will need:** *Potato, borer/knife, sucrose solution (0%, 5%, 10%, 15%), 4 beakers, measuring cylinder, ruler, weighing balance.*

**Procedure:**

(**Note**: *you are welcome to adapt the procedure to investigate different solutes and/or different living tissues. You may also choose to use samples of different dimensions. Carry out your own research using the internet to*

***design an experiment that will produce conclusive results. Alternatively, follow the method below):***

1. Make up the four concentrations of sucrose solutions.
2. Pour 50cm$^3$ of pure/distilled water into beaker 1, 50cm$^3$ of 5% sucrose into beaker 2, 50cm$^3$ of 10% sucrose into beaker 3, 50cm$^3$ of 15% sucrose solution into beaker 4.
3. Use the borer to remove 4 cylinders from the potato.
4. Cut the potato cylinder into 3cm lengths and dry with a paper towel.
5. Measure the mass, diameter, and length of each potato piece.
6. Record the results.
7. Place one potato cylinder into each beaker.
8. Leave for 24 hrs.
9. Record the mass, diameter, and length of each potato cylinder.

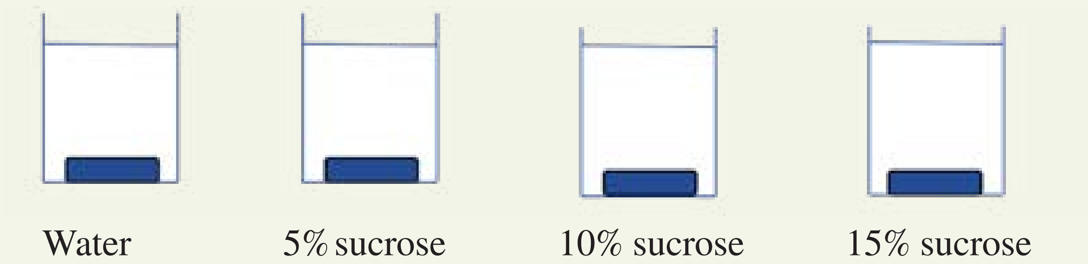


**Fig (b):** Investigating osmosis in plant tissue

Now record your results in Table 3.2

## Observation/Results:

**Table 3.2**

| BEAKER | solution | Length/mm | | | Mass/g | | | Diameter/mm | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Start | After 24hrs | Change | Start | After 24hrs | Change | Start | After 24hrs | Change |
| 1 | water | | | | | | | | | |
| 2 | 5% sucrose | | | | | | | | | |
| 3 | 10% sucrose | | | | | | | | | |
| 4 | 15% sucrose | | | | | | | | | |

### Data analysis:

For each concentration of sucrose solution:

**1.** a. Calculate the percentage change in mass.

**Hint**: percentage changes can be found by finding the difference between the original value and the new value, then dividing this by the original value. Multiply your result by 100 to find the percentage change. Note that if the new value is less than the original value then the difference is negative and therefore the percentage change is also negative.

b. Calculate the percentage change in length.

c. Calculate the percentage change in diameter.

d. Explain your observations.

**2.** Draw a line graph to present some of the results with sucrose concentration on the x-axis and percentage change in mass (or length or diameter) on the y-axis.

**3.** Present your findings to the rest of your class in a 3-minute oral presentation using visual aids if possible. Ensure that everybody in your group has a role in the presentation.

## EXTENDED READING

Click on the links for more information on transport in living things and on osmosis.

- https://unacademy.com/content/wp-content/uploads/sites/2/2022/10/Transport-in-Plants.pdf
- https://biologyreader.com/endosmosis-examples.html
- https://www.youtube.com/watch?v=qGALyEW4ZFY
- https://www.youtube.com/watch?v=30yV3RaU03g
- https://www.youtube.com/watch?v=PKsTsmD6b1k
- https://www.youtube.com/watch?v=povvINECyb0
- https://www.youtube.com/watch?v=55W29p6sgJ0

# ANNEXES

## Annex 3.1 – Solutions to Activities on Diffusion

### Activity 3.1

- **Concentration gradient**: The concentration gradient is the difference in concentration between two regions. The greater the concentration gradient, the faster diffusion will occur.
- **Temperature**: Temperature directly affects particle kinetic energy. Higher temperatures increase the kinetic energy, causing particles to move more vigorously. As a result, diffusion happens at a faster rate in higher temperatures. Conversely, lower temperatures lead to slower diffusion due to reduced particle movement.
- **Particle size/molecular weight**: Smaller particles diffuse more quickly than larger particles. Collisions with other particles hinder smaller particles. Larger particles, on the other hand, have more mass and experience greater resistance, leading to slower diffusion rates.
- **Nature of media through which diffusion is occurring**: Diffusion occurs faster in less dense or viscous media. For example, it occurs more rapidly in air than in a thick liquid.

### Activity 3.2

**Observation:** When a Potassium permanganate crystal is placed in water, the crystal dissolves and the permanganate ions are concentrated in one area.

As the crystal dissolves in the water, a net movement of permanganate ions occurs throughout the beaker of water.

The water and the permanganate ions are eventually equally distributed throughout the beaker.

**Conclusion:** Permanganate ions move from an area of high concentration to an area of low concentration until the ions are evenly distributed.

**Activity 3.3**

**Observation:** You will smell the perfume sooner if you sit at a short distance from the perfume bottle, and as the distance increases the time taken to smell the perfume increases (as the perfume molecules diffuse throughout the classroom).

**Conclusion:** Diffusion of gas particles also occurs as the perfume evaporates forms a cloud of high perfume concentration and diffuses throughout the classroom until the gas is evenly distributed throughout the classroom.

## Annex 3.2 – Solutions to Activities on Osmosis

**Activity 3.4**

**1.** Name a common household substance that contains *solvent* molecules.

Paint, ink, nail polish.

**2.** Name a common household substance that contains *solute* molecules.

Alcohol, water, salt, sugar.

**3.** (i) From the illustration, which molecules are moving?

The solvent molecules.

(ii) In which direction are the molecules moving?

To the left.

**4.** Describe the solutions A and B.

Solution A is a solvent and solution B is a solute.

**5.** What process is causing the molecules identified in 3(i) to move?

Osmosis.

## Activity 3.5

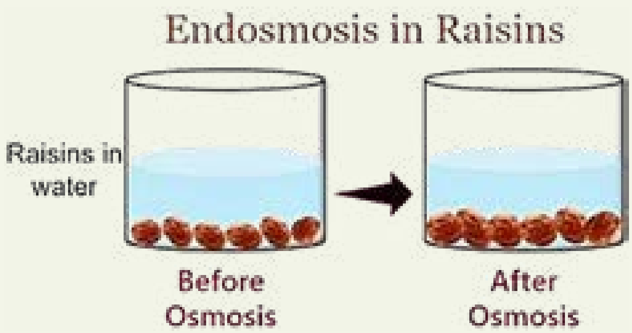


**Fig.(a):** An example of osmosis using common household items (raisins and water)

**Explanation:** There has been a net movement of water molecules across a membrane from an area of high concentration to an area of low concentration.

## Activity 3.7

**Explanation:**

The Visking tubing acts as a semi-permeable membrane just like a cell membrane.

The water concentration was higher in the beaker than inside the model cell (aside from the 0% sucrose solution, which was equal to the concentration of the water outside). Water then moved through the tubing from the outside to the inside and the model cell increased in circumference and felt firmer.

## Activity 3.8

**Explanation:**

The potato cell membrane acts as the semi permeable membrane. There is a difference in the concentration of water in the cells making up the potato tissue and the concentration of water in the solution.

- In beaker 1, the highest concentration of water is outside the cell in the beaker. So, water moves into the potato tissue. The cells expand leading to an increase in length, mass and diameter of the potato cylinder.
- In the beakers 2, 3 and 4 water is likely to either move into the potato, increase the measurements (length, mass and diameter), or out of them leading to a decrease of them.

- If there is no change in the measurements, then water has not moved because concentrations on either side of the semi-permeable membrane are equal. Using this knowledge, we can use our line graph to find the concentration at which there is a zero percent change in the mass/length/diameter of the potato. This tells us the concentration of the potato itself.

## Annex 3.3 – Further Information

### APPLICATIONS OF OSMOSIS IN EVERYDAY LIFE

**Food Preservation**: Osmosis is utilised in food preservation techniques such as pickling and curing. In these processes, salt or sugar is used to create a high concentrated solution, which draws water out of the food and the microorganisms present in the food. This removal of water inhibits the growth of bacteria and other spoilage-causing organisms, thus extending the shelf life of the food.

Below is a link that will explain the preservation process better to you:

https://www.youtube.com/watch?v=PKsTsmD6b1k

**Kidney Function:** Osmosis is integral to the functioning of the kidneys, which filter waste products from the blood and regulate water and electrolyte balance. The movement of water and solutes across the renal tubules occurs through osmosis, allowing the kidneys to concentrate urine and reabsorb necessary substances back into the bloodstream.

Below are two links that will explain osmosis in kidney function better to you:

1. https://www.youtube.com/watch?v=vdNwdC7eCT0
2. https://www.youtube.com/watch?v=OEzKQmqV2WQ

**Brining**: Brining is a process used to enhance the flavour and juiciness of meat, poultry, and fish. It involves soaking the food in a solution of salt and water. During brining, osmosis occurs as the salt concentration in the brine is higher than the concentration of salt in the meat or fish. Water moves from the meat or fish into the brine, resulting in decreased moisture content and improved flavour.

Below are links that will explain osmosis in brining of meat better to you:

1. https://www.youtube.com/watch?v=povvINECyb0
2. https://www.youtube.com/watch?v=55W29p6sgJ0

# REVIEW QUESTIONS

## Review Questions 3.1

1. A man walking behind the kitchen of a house was able to smell the nice aroma coming from the soup being prepared. Explain how he was able to smell the scent of the soup.
2. Give at least three examples of diffusion in everyday life.
3. When the weather is hot, and a baker is baking bread the aroma goes farther from the bakery. What is the explanation for this?
4. What role does diffusion play in biological systems?

## Review Questions 3.2

1. A boy accidentally watered a potted plant with salt solution. The next morning it was found that the plant was dying. Suggest a possible means for him to revive the plant. Explain your answer.
2. In dry Harmattan seasons most plants with shallow roots usually do not survive. However, plants with deep roots do survive. Briefly explain why this is so.
3. Ama and Ali (group A) and Emefa and Adjetey (group B) were performing an experiment to demonstrate osmosis. With all other factors being equal, Group A used water at room temperature while Group B used warm water. Whose experiment will be faster and why?

# ANSWERS TO REVIEW QUESTIONS

## Review Questions 3.1

1. The man was able to smell the aroma of the soup being prepared in the kitchen due to the process of diffusion.

   Diffusion is the movement of molecules from an area of high concentration to an area of low concentration. In this case, the aromatic molecules from the soup were released into the air and gradually spread out, reaching the man's location by diffusing through the air.

2. Here are three examples of diffusion in everyday life:

   - Perfume or cologne spreads through a room as the fragrance molecules diffuse through the air.
   - The smell of fresh-baked bread or cookies wafting from a bakery as the aroma molecules diffuse outward.
   - The gradual mixing of sugar or salt in a glass of water as the solute molecules diffuse throughout the liquid.

3. When the weather is hot, the aroma from the baking bread can travel farther from the bakery due to the increased kinetic energy of the air molecules. In hot weather, the air molecules have more thermal energy and move faster, which enhances the rate of diffusion. This allows the aromatic molecules from the bread to spread out more quickly and reach a larger area surrounding the bakery.

4. Diffusion plays a crucial role in various biological systems:

   - Gas exchange in the lungs: Oxygen and Carbon Dioxide molecules diffuse across the alveolar-capillary membrane during respiration.
   - Nutrient absorption in the digestive system: Nutrients, such as glucose and amino acids, diffuse from the lumen of the intestines into the bloodstream.
   - Cell membrane transport: Certain molecules, like water and Oxygen, can diffuse across the cell membrane, while others require active transport mechanisms.

- Signaling in the nervous system: Neurotransmitters and ion molecules diffuse across the synaptic cleft during the transmission of nerve impulses.
- Diffusion of hormones and other signalling molecules within the body, allowing for communication between different tissues and organs.

## Review Questions 3.2

1. You should flood the soil around the plant with water. Watering the plant with salt solution increases the solute molecules outside the root cell sap. This causes water molecules to move out of the cell (where they are at a higher concentration). The plant wilts and will eventually die.
2. There is less water in the shallow soil during the Harmattan season. This causes water to move out of the root hair cells into the soil leading to the death of the plants. The deep-rooted plants have access to soil with a greater water concentration.
3. Group B. Molecules of the warm water gain kinetic energy causing them to move faster. The higher the temperature the faster the rate of osmosis.

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