Learning from Raisins

Overview

In most biological processes, the displacement of molecules from one place to another requires chemical energy. Such displacement driven by chemical energy is known as active movement. On the other hand, diffusion and osmosis are two essential biological processes where no energy is required to displace molecules from one place to another. Such displacement which is not driven by chemical energy is known as passive movement. Among the two, osmosis is considered as specialised diffusion. This unit aims at improving the student's understanding of the concept of osmosis. Through this unit, students will learn that there is only a net movement of water molecules across the membrane in the process of osmosis. They would know how a concentration difference works for the movement of solvent (water) across a membrane. Students can be engaged in this by performing an experiment using raisins.

Concept of osmosis

In a given system, the movement of a molecule from its higher to lower concentration is known as diffusion and it continues till the concentration difference gets reduced and becomes almost zero. Diffusion happens when there is no physical barrier present between regions along a concentration gradient e.g. ink drop diffusing in water. Osmosis is also a type of diffusion, but here the movement of **only solvent molecules** i.e. water takes place across a semipermeable membrane* (e.g. the plasma membrane of a living cell). There is a solution of higher solvent concentration on one side and a solution of lower solvent concentration on the other side of the membrane. It can be stated in another way that osmosis is a process in which only water molecules can cross the membrane barrier to move from a lower **solute** concentration to a solution of higher **solute** concentration. Net osmotic movement stops as soon as the solute concentration on either side of the semipermeable membrane becomes equal.

In the case of living cells, water plays a major role as a solvent. A certain concentration of water and other solutes needs to be maintained inside the cell. This is necessary to maintain the structural integrity and functional activity of cells. The osmotic movement of water through the cell membrane plays an important role in maintaining cellular integrity and activities.

*Semi-permeable membrane OR selectively permeable membrane is a biological or synthetic barrier/ thin sheet that allows certain molecules to pass through it while others are restricted. It works like a sieve. In the case of osmosis, it is permeable to only water molecules.

Time required: 3 sessions of 40 min each

Type of learning unit: Laboratory based

Learning objectives: After working on this learning unit, students will be able to

- Understand the concept of 'osmosis'
- Identify the difference between osmosis and diffusion
- Recognize the role of osmosis in certain biological processes
- Recognize selectively permeable membranes for water in many systems.

Links to curriculum:

- Class IX Chapter 5: The Fundamental Unit of Life

Introduction

When we add a drop of ink to water, the ink starts spreading throughout the water (solvent). Similarly, if we add a spoonful of salty water to a glass of water, the whole water becomes salty after some time. It means that when a substance present in a high concentration in a liquid comes in contact with a liquid having a lower concentration of that substance, diffusion of substance from a high concentration region takes place spontaneously and it spreads out. However, when we put a barrier between these liquids like a plastic or metal sheet, diffusion should not happen!

However, in nature, we have certain special barriers that can stop the diffusion of some substances and allow other substances to pass through them. An example is peels of some vegetables, or membranes in our body cells. Such special barriers are known as semi-permeable membranes and can lead to special kinds of diffusions.

Now, we will perform a small experiment using raisins (produced by drying grapes) to study a special kind of diffusion.

Materials: (Requirements for 3-4 groups)

- 100 g Raisins (dry)
- 200 g Sugar or Sucrose
- Food colour (green/blue/red – any one)
- 1 weight balance (pocket scale)
- 500 mL Water (Clean tap water)
- [Per group] 5 Glass or plastic containers of 50 mL capacity, 2 beakers of 100 mL capacity, 1 Measuring cylinder (10 mL capacity), forceps without sharp point
- [Optional] 1 Insulin syringe (It has a fine needle to make very small prick in raisins)

  Note: Raisins are readily available in any grocery store. While buying, please check that they are intact, medium or large-sized (around 1 cm or above in length) with greenish yellow or light brown coloured. While selecting for the experiment, do not use very dark brown, small, deformed fruits. Preferably choose fruits with undamaged stalks.

Task 1. Preparing for the experiment

Prepare the following solution (the quantities mentioned are sufficient for 3-4 groups of students, each group doing a set of experiments).

1. 40% Sucrose solution: Dissolve 20 g sugar in 25-30 mL of water. When all the sugar dissolves, make up the volume to 50 mL.
2. Saturated Sucrose solution: Take 50 mL water in a beaker or container and add ~40-50 g of sugar. Try to dissolve it as much as possible. This is closer to a saturated solution of sucrose.
3. Food colour solution: Dissolve a pinch of food colour in around 5 mL water to make a concentrated solution.

> The teacher may have a short discussion and demonstration on how to use measuring cylinder and weighing balance (tare – setting zero before weighing).

Task 2. Fun with raisins

1. Take 3 containers of 50 mL capacity or 50 mL beakers. Label them with numbers 1 to 3.
2. Weigh about 7-8 raisins (use entire ones without breaking their stalks) and record the weight in Table 2. Put them in container no. 1. Similarly add weighed raisins in containers no. 2 and 3.
3. Add 10 mL of water in container no. 1. All raisins should get completely immersed. If not, add another 5 mL of water but *remember to keep amount of solution constant in all the 3 containers.*
4. Add 10 mL of 40% sucrose solution in container no. 2 and 10 mL of saturated sucrose solution in container no. 3.
5. Now put 2-3 drops of food colour solution in container no. 1, 2 and 3. Mix it well by gently swirling.
6. Summarize the constituents of your containers in Table 1.
7. Cover all the containers to avoid evaporative loss of liquid. Note the time and keep them undisturbed for 45 minutes. In the meantime, try answering the following questions.

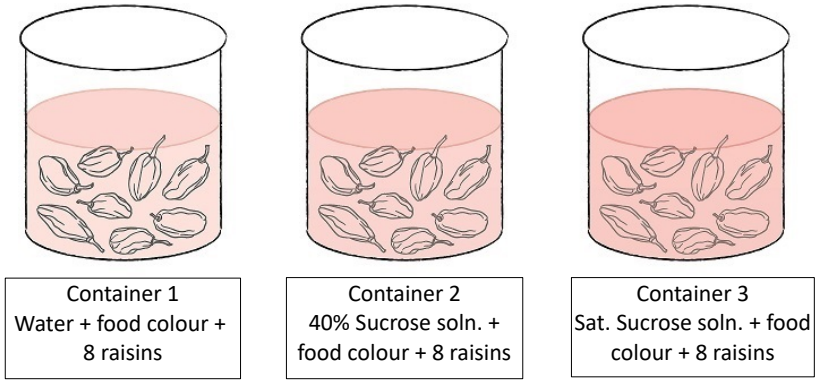

Figure: Containers with their constituents

Notes:

1. Raisin sizes vary from place to place therefore teachers can decide the quantity of liquid being added. If the raisins are large, they can either increase it to 15 or 20 mL or reduce the number of raisins.
2. The main purpose of this activity is to show how osmosis works if the concentration gradient across the membrane is altered. Therefore, two extremes and one middle concentration are used to obtain a clear difference in results.
3. A little excess amount of liquid (around 5 mL) above what is required for immersing all raisins is recommended. It will help in reducing an error occurring during transfer. The loss happening due to liquid stuck to raisin surface is more or less similar in all containers and it is in microlitres.
4. If the time is extended above 45 minutes, (e.g. 90 or 120 minutes) the results will be more prominent but overnight soaking may not be helpful as excess swelling may lead to membrane rupture and results will alter.

To demonstrate that no other molecules (other than water) come out of raisins during soaking, the teacher may put a fourth container (of same 50 mL capacity) and label it number 4. For this container:

- Weigh about 7-8 raisins (use entire ones without breaking their stalks) and record the weight. Put them in container no. 4.
- Add 10 mL of water (or the quantity you added in container 1) in container no. 4.
- Now use an insulin syringe to inject a drop of food colour solution in 7-8 raisins. Inject the colour slowly and carefully. Do not try to inject excessive dye forcefully. (Just a drop is enough)

- Weigh these dye-injected raisins and put them in container no. 4.
- Add 2-3 drops of water in container 4 instead of food colour.

It is strongly recommended that the students should not be allowed to handle the insulin syringe and the setup for container no. 4 should be strictly prepared and handled by the teacher. We added 2-3 drops of water in container 4 instead of food colour. Why it was necessary?

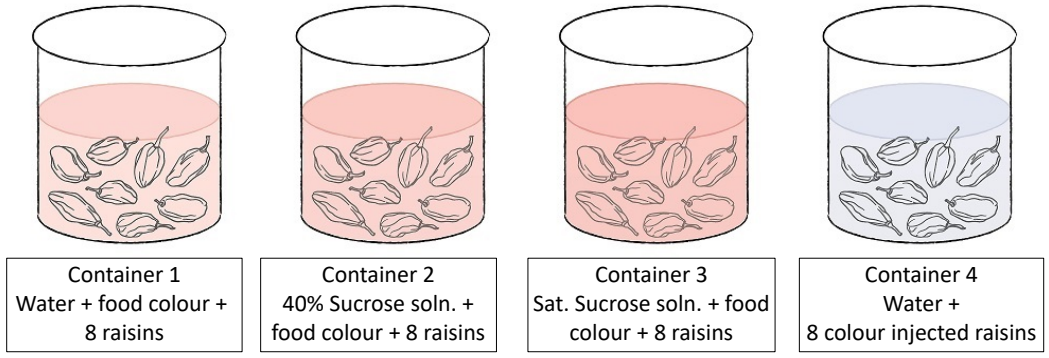

Table 1: Summarize the contents of each container in the table below (+ represents added and – represents not added):

Container no.	Raisins (Dry)	10 ml Water (+/-)	10 ml Sucrose Solution (+/-)	Food colour in water (+/-)
1				
2				
3				

Q1. What do you think is the role of dye (food colour) in this experiment?

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Q2. What do you expect will happen in each of the containers?

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- After about 45 minutes, carefully remove raisins from container no.1 using forceps having blunt ends. Do not prick/damage the raisin while holding it with the forceps. Gently tap it to the side wall of the container side to drain off excess liquid. Observe any change in shape/ colour of raisins, and note in Table 2.
- Gently blot the raisins (dry their surface) on tissue paper and weigh them together.
- Measure the amount of water in container no.1 using measuring cylinder. Note down your observation in Table 2.
- Repeat it for the rest of the containers.

Table 2: Write about the shape before and after and also the volume of liquid from each container. The shape can be categorised as 'more shrunken', 'no change' or 'swollen'. (the original shape while starting the activity should be considered as 'Shrunken')

Container No.	Shape of raisins		Mass of raisins (mg)			Approximate Volume of liquid in container (mL)		
	Initial	Final	Initial	Final	Difference	Initial*	Final	Difference
1.						10		
2.						10		
3.						10		

*Can be 15 or 20 mL as per the requirement. But should be constant in all containers.

Q1. Now that you have recorded all the details and done all calculations, can you tell if the mass difference is same in all containers? If the initial mass of raisins is different in different containers, then calculate the mass difference per gram of raisins to compare.

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> The teacher may summarise differences in mass and volume of each container for all groups on black-board. That might help in finding similarities with other groups. Also, discuss with students the need of calculating mass difference per gram. As initial mass of same number of raisins might be different.

Q2. Why did the raisins change in shape?

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Q3. What according to you was going inside the raisin?

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Q4. Why were different concentrations of sucrose used?

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Q5. What happens in container no. 3?

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Q6. Why is this not a simple diffusion? Which container can be used to demonstrate?

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Q7. Was the change in the mass of raisins in each container related to the change in the water volume you observed for that container?

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Q8. Was any semi-permeable membrane present in the above experimental setup? If yes, what did it allow to pass through and what did it stop from passing through?

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Cells of dried raisins contain natural sugar stored in dissolved form inside the cytoplasm. This sugar solution has very little solvent (water) content while its sugar concentration is considerably high. The cellular membrane and raisin skin allows only water molecules to pass through.

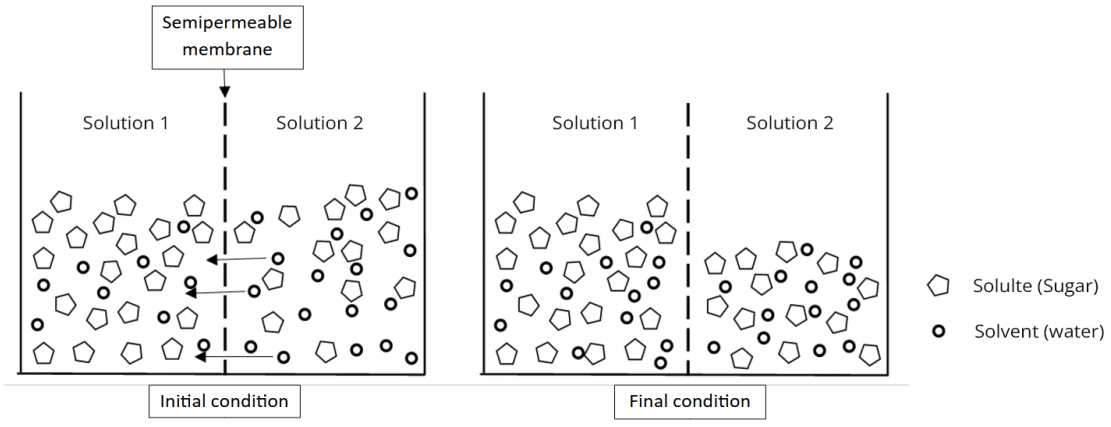
In container 1, there is a large concentration difference in the water content inside the cell (low) and surrounding coloured water (high). Therefore, endosmosis takes place. Since colour molecules cannot enter inside, the raisins remain colourless.

Container 2 and 3 show gradual decrease in water concentration in the surrounding solution as sugar concentration is increasing respectively. The concentration gradient is reduced which results in lesser amount of solvent (water) entering in the raisins. This can be checked by the raisin weight.

Container 4 has raisins with a small amount of colour injected inside. All other conditions are same as container 1. This is mainly responsible for proving that the molecular movement is purely osmotic and not by diffusion, otherwise the water will get coloured after some time (some colour leaks out due to pricking but it doesn't make surrounding water substantially dark coloured).

Task 3. A look at osmosis

Net movement of water across a semipermeable membrane from a solution of lesser to one of greater solute concentration is known as osmosis. The membrane must be permeable to water but not to solute molecules. One should not confuse it with imbibition, which is a diffusion of water in colloidal solids (mostly proteins in biological systems) which results into swelling of latter. Eg. Pulses soaked in water. Imbibition never takes place between two liquids of differing concentrations.



Representation of movement of solvent molecules

The figure above is given for representative purposes. Pentagons represent sugar or any molecule that cannot pass through the middle membrane while circles represent water molecules which can readily cross the membrane. Initially two sugar solutions of different concentration are added on two sides of semipermeable membrane. As it can be seen, left compartment has higher sugar concentration than right. But membrane does not allow sugar molecules to diffuse towards right compartment of lower solute (sugar) concentration. Water molecules being in higher concentration on right side can cross the membrane and move towards its lower concentration. The net movement stops when water molecules OR solvent concentration becomes equal on both sides. It is shown in 'final condition.' *(For ease of understanding, pressure difference is not considered here.)*

Q1. Table below presents a few situations. These situations may involve one or more of the processes (diffusion, osmosis, or imbibition). Indicate the predominant process (diffusion or osmosis). If the process is osmosis, identify the semi-permeable membrane in the example.

	Situations	Diffusion / osmosis	Semi-permeable membrane (if osmosis)
i	Gulab jamun dipped in sugar syrup after frying.		
ii	Whole raw mango stored in salt solution becomes salty from inside.		
iii	Potato slices sprinkled with salt become wet		
iv	Adding sabza (sweet basil) seeds in water.		
v	Intake of water from soil in plants		
vi	Dipping tea bag in hot water for making tea		

1. *Diffusion: Sugar as well as water, both entering gulab jamun indicates that there is no membrane separation.*
2. *Diffusion: In a brine (high-concentration solution of salt), raw mango skin being permeable to water as well as Na^+ and Cl^- ions, the solute (salt ions) and solvent (water) both diffuse inside raw mango as the concentration of both solvent and solute inside is very low as compared to outer solution.*
3. Osmosis: Slicing of potato cuts and opens many cells which makes the surface moist. Sprinkled salt dissolves and forms a very thin film of salt solution. Potato slice surface also has a large number of intact cells. Their cell membrane comes in direct contact with very high salt concentration. The (solvent) water content of cytoplasm is high compared to outer film of salt solution (where

concentration of solute is high and solvent is low). The Cell membrane acts as a semipermeable membrane and water moves from its higher concentration to outer lower concentration.

4. Osmosis: The seed coat cells have very low water content so water enters the pericarp by osmosis and helps in forming mucilage around the seed. If the seeds are dipped in sugar solution, endo-osmosis doesn't occur efficiently.
5. *Osmosis: Plants absorb water from the soil through their roots via osmosis, with water moving from the soil (high water concentration) into the root cells (lower water concentration).*
6. Diffusion: When a tea bag is put in hot water, the soluble tea compounds diffuse into the water, giving the water colour and flavour.

Q2. Certain membranes allow water to pass through but not sugar. Can you give examples of such membranes?

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Opening and closing of leaf stomata also involves swelling and shrinking of guard cells. Is it likely that this process may be happening due to osmosis? Discuss among your friends.

Q3. These days we hear a lot about RO filters in water purification units. RO stands for reverse osmosis process. RO filters are used to get rid of excess salts and minerals dissolved in water. Can you find out why it is called 'reverse' osmosis?

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Q4. There are some factors mentioned in the following table that may or may not affect both the processes, and some factors play a key role in these processes, i.e. diffusion and osmosis in aqueous solutions. Put a tick (√) in the appropriate boxes as per your understanding:

	Factors involved/affecting	Diffusion	Osmosis
A	Solute movement		
B	Water movement		
C	Semi-permeable membrane		
D	Concentration difference		
E	External heating		

Physical factors like temperature, pressure and weight also affect the rate of diffusion and osmosis. For e.g. Higher temperature accelerates both the processes, but are not necessary for the processes to take place.

Q5. There are many fishes that live in marine water. How do you think they survive in such salty water (without losing their body water or without absorbing outside water)?

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Marine fish lives in water with higher salt concentration than its cellular level. Therefore, it undergoes exosmosis continuously. Body loses water to surrounding environment as it moves from its higher concentration (inside the body) to lower concentration (marine water). To compensate this loss, it keeps drinking water continuously and also produces very less amount of urine which has high solute concentration (hypertonic urine).

Q6. Can you think of any examples in the human body/environment where osmosis plays an important role?

Suggestions for Extended Tasks

- Students can work out several variations by changing parameters like
  - Different solvents (Alcohol, liquid soap)
  - Temperature (low or high)
  - Type of solute (salt, soda)
  - weight of raisins
- They can use different biological materials like dried fig, dried vegetables, fruits, *sabza* etc. and try a similar experiment.

Suggested Reading

Nagarjuna G (2021). Common misconceptions in biology: Misconceptions around diffusion and osmosis. In IndiaBIoScience Columns. https://indiabioscience.org/columns/education/common-misconceptions-in-biology-misconceptions-around-diffusion-and-osmosis

