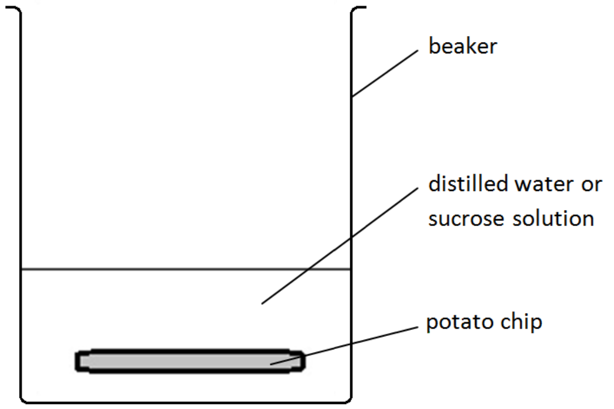
To do

1 Set up the potato investigation as instructed.

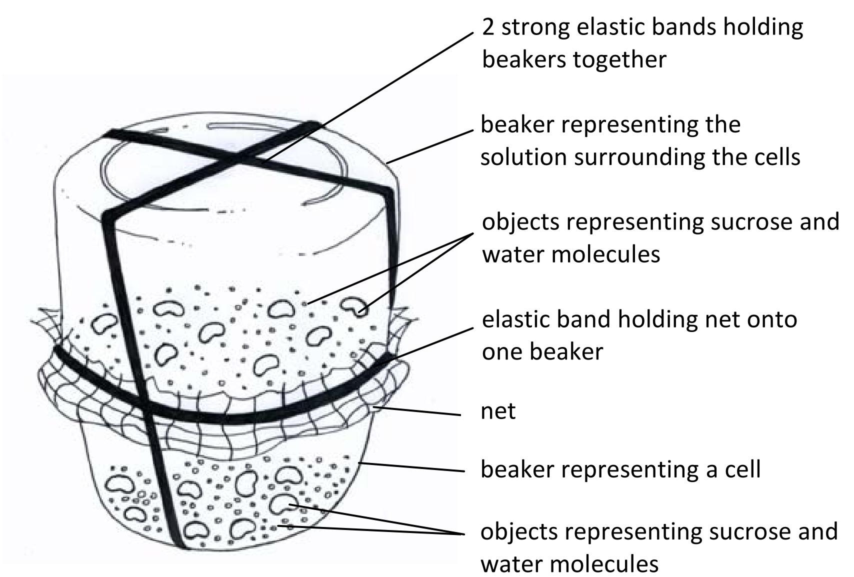


2 Record the mass of the potato which is then placed in distilled water. .... g

3 Record the mass of the potato which is then placed in concentrated sucrose solution. .... g

4 Potato cells contain a weak sucrose solution. In your pair, build a pot model to represent either potato in distilled water, or potato in concentrated sucrose solution.

The 'pot model' will be used to represent the movement of water across a partially permeable cell membrane.



5 Record the results, from your pair and another, in the table below.

	Potato in distilled water	**Potato in sucrose solution**
What happened to the 'water' molecules on each side of the model's 'membrane'?		
What happened to the 'sucrose' molecules on each side of the model's 'membrane'?		

To answer

1 For each potato chip in your experiment, use the pot model to predict what will happen to:

a the water molecules in the cell and the solution.

....

b the sucrose molecules in the cell and the solution.

....

2 Predict whether the chips will stay the same mass, or how they might change. Explain your predictions.

....

....

....

3

Record the mass of the potato which has been in distilled water for 15 minutes. .... g

Record the mass of the potato which has been in concentrated sucrose solution for 15 minutes. .... g

For each potato chip describe any changes in mass.
Were your predictions correct?

....

....

....

....

4 You will be presented with a new model for osmosis.
Use the revised model to explain the results of the potato investigation.
Use scientific terms in your answer.

....

....

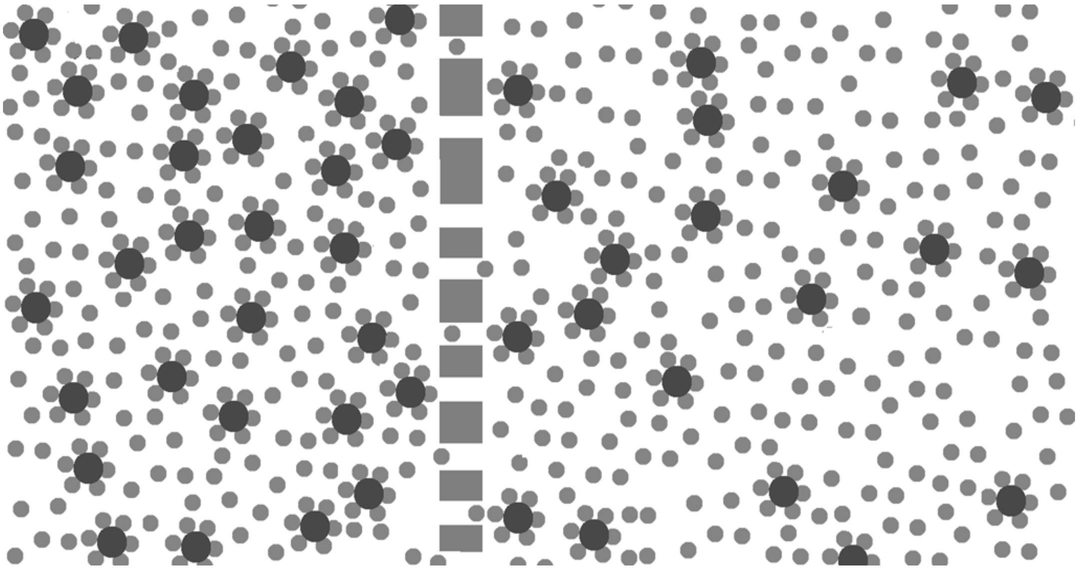
....

....

....

Using a 'pot model' to represent osmosis: Assessing learning

Follow the instructions on this page to use the diagram below as a different model for osmosis.



To study

The sucrose solution is more concentrated than the contents of the potato cells. This 2-D diagram model should help us to predict or explain what happens when a piece of potato is placed in a strong sucrose solution.

To do

1 In the diagram, identify and label the two different types of molecule and the cell membrane.

2 Show on the diagram which part represents the solution, and which part represents the inside of a potato cell.

3 Add arrows and notes to explain any movement of water between the potato cell and the solution.

To answer or to discuss

1 Explain how you can use this model to predict whether or not a potato chip might change in mass when left in solutions of different concentrations.

2 How does this model help to explain how plants get water from the soil?

3 Explain how the 'pot model' helped you to think about osmosis.

Learning structure of the lesson

The big picture

This lesson is designed to exemplify a model-based inquiry approach to practical work in which students make, use and evaluate models for osmosis.

Osmosis is an important process which allows plants to take up water. A model can be used to help explain how this process works, and to make predictions. In this lesson students make and use a 3-D model for osmosis and evaluate the 3-D model compared to a more familiar 2-D model for osmosis.

Age range: 14–16

Timing: 2 x 50 minutes (ideally as a double lesson).

1: Learning episode 1 (teacher-led) 10 mins

Ask students how plants take up water. Share the learning outcomes for the lesson and introduce the context for the practical investigation.

1: Learning episode 2 (student-led) 20 mins

Students leave the potato chips to soak in a water and sucrose solution.

Review plant cell structure and introduce a simple model for osmosis.

1: Learning episode 3 (student-led) 20 mins

Students work in groups to build ‘pot models’ to simulate osmosis. They predict what will happen to potato cells in water and sucrose solution and then test their predictions using the models.

2: Learning episode 4 (student-led) 15 mins

Students record the mass of the potato chips which have been left to soak, then consider whether the results match their predictions. The change in mass is linked to the net movement in water.

2: Learning episode 5 (teacher-led) 25 mins

The simple model for osmosis does not correctly predict the change in mass and so needs to be refined. Introduce the refined model for osmosis and students use this new model to explain their results.

2: Learning episode 6 (student-led) 10 mins

Students work in groups to suggest how their ‘pot models’ could be modified and improved to account for the findings.

Learning outcomes

Students will be able to:

- construct and apply a model of osmosis
- explain the overall movement of water into and out of plant cells

Equipment and materials

Teacher guidance
Practical guidance
Slide presentation
Student sheets
Interactive

Per group/pair
Small plastic pots or beakers of equal size and shape, 2
Strong elastic bands, 3
Piece of netting
Labels or pens
Large baking potato
Distilled water, in wash bottle
Cork borer, or potato chipper
Beakers (100 cm^3), 2
White tile
Knife
Ruler
Measuring cylinder (50 cm^3)
Teat pipettes, 2
Per class
Items representing water molecules
Larger items representing sucrose molecules
Sucrose solution, 556 g / dm^{-3}
Access to balances

Refer to the health and safety advice and practical guidance

Key words

Atom, molecule, partially-permeable membrane, diffusion, solution, concentration, model

Prior knowledge

It is assumed that students know the following.

- All matter consists of molecules or atoms that are constantly moving.
- The random motion of atoms or molecules in liquids means that they spread from areas of high concentration to areas of low concentration. This is the definition of 'diffusion'.
- Plants need water to grow; they get this water from the soil.
- Cells are surrounded by a partially-permeable cell membrane. This allows some chemicals through, but is a barrier to other chemicals.
- The plant cell wall is freely permeable.

Background information

When solutes dissolve in water, weak bonds form between the water and solute. For this reason, water molecules in a solution are less free to move across a partially-permeable membrane compared with water molecules in pure water.

Water molecules and solute molecules move randomly in solution. Osmosis is the result of molecules colliding with pores in the membrane; water molecules going through and solute molecules not going through.

Osmosis is the 'net' or overall movement of water by diffusion through a partially-permeable membrane, from a solution of lower concentration to a solution of higher concentration of dissolved solutes.

Time management

- Your technician could provide potato chips trimmed to an exact, known mass or help by assessing the mass of the chips at the beginning of the lesson.
- The 'pot models' could be made as a homework exercise or in a previous lesson. The students could then add the 'solute' beans and use the models during the lesson.

Terminology

The terms which students need to understand and use in this lesson are:

atom – the smallest particle of a defined element

molecule – a group of two or more atoms held together by covalent bonds

partially-permeable membrane – a membrane which will only allow certain molecules (or ions) to pass through it by diffusion

diffusion – the spread of particles through random motion from regions of higher concentration to regions of lower concentration

solution – a mixture in which a solute (e.g. sucrose) is dissolved (forms weak bonds with) a solvent (e.g. water)

concentration – the amount of solute (e.g. sucrose) in a certain volume of solvent (e.g. water)

model – a mentally visualisable way of linking theory with experiment. They enable predictions to be formulated and tested by experiment.

Differentiation

With some students it may be appropriate to use a drama activity to model the osmosis process.

Students take on the role of the molecules, either ‘water’ or ‘sucrose’, and are identified by different coloured bands or hats. A ‘semi-permeable membrane’ is created using a line of chairs or other barriers.

When a ‘water’ molecule becomes attached to a ‘sucrose’ molecule, becoming part of a three or four molecule ring around the sucrose, the water molecules are no longer free to move through the gaps (pores) in the ‘semi-permeable membrane’. Unattached water molecules can pass through the pores.

It is difficult to mimic the random movement of molecules, but the simple message which should be conveyed is that ‘sugar can’t cross the membrane, but water can’.

Taking it further

Students apply and refine the model to explain how salt marsh plants are able to take up water.

A full investigation could be carried out to find the concentration equal to the concentration of the potato cells (or other plant tissue).

Related practical activities on Practical Biology

Investigating the effect of concentration of blackcurrant squash on osmosis in chipped potatoes:
www.nuffieldfoundation.org/practical-biology/investigating-effect-concentration-blackcurrant-squash-osmosis-chipped-potatoes

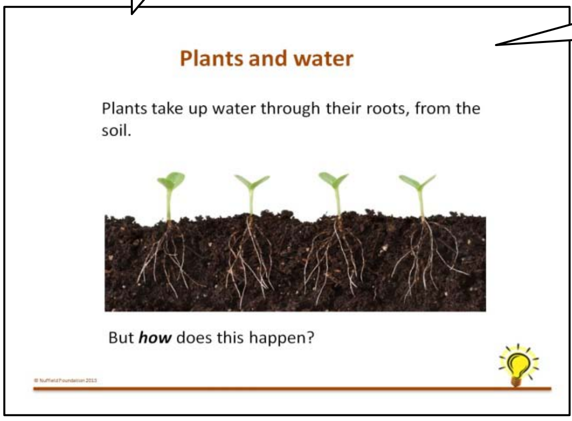
Investigating osmosis in chickens eggs:
www.nuffieldfoundation.org/practical-biology/investigating-osmosis-chickens%E2%80%99-eggs

Observing osmosis, plasmolysis and turgor in plant cells:
www.nuffieldfoundation.org/practical-biology/observing-osmosis-plasmolysis-and-turgor-plant-cells

A closer look at blood:
www.nuffieldfoundation.org/practical-biology/closer-look-blood

Lesson details – lesson 1

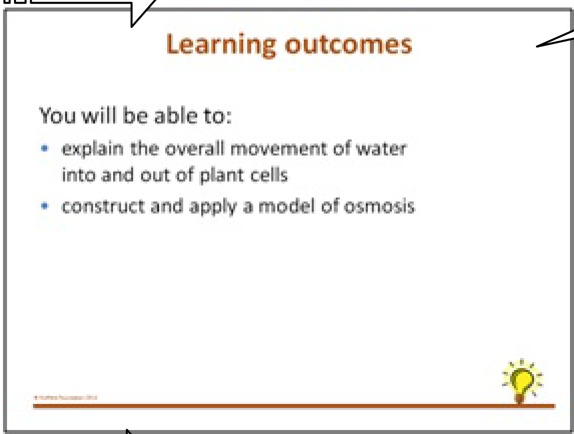
Slide 2



Explain: All gardeners know that plants need to be watered. Plants take up water through their roots from the soil, but how does this happen? (**slide 2**)

This is the phenomenon being explored in this lesson, by using the 3-D and 2-D models.

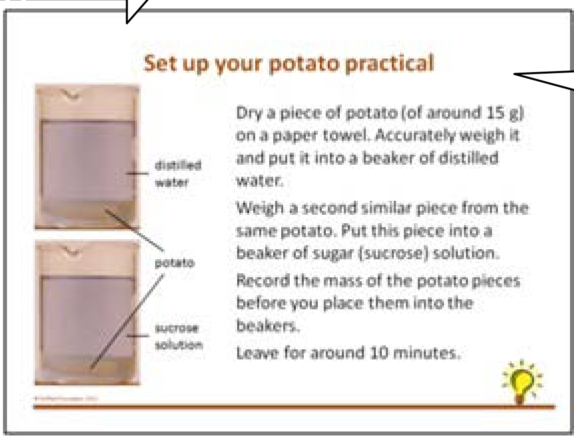
Slide 3



Task: Use **slide 3** to share the learning outcomes for the lesson.

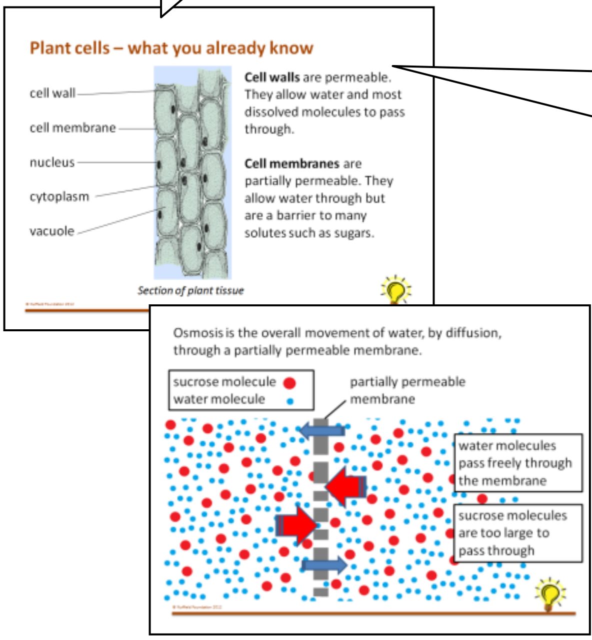
Explain: Potatoes are parts of plants. Students will use potato to study how plants take up water by seeing how chips of potato take up water.

Slide 4



Task: Students follow the instructions on **slide 4** to set up the potato chip investigation (see **Practical activity part 2**), and leave the chips to soak.

Slides 5–6



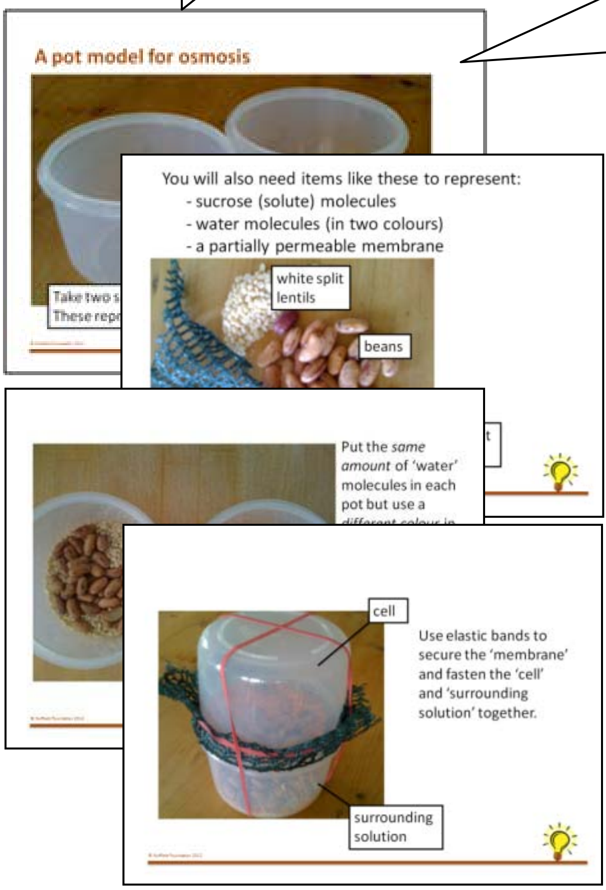
Task: Use **slides 5 and 6** to review plant cell structure and introduce a simple model of osmosis. Relate this to students' prior knowledge of diffusion. Emphasise how water passes in both directions across a membrane, so osmosis relates to the overall (net) flow over time.

Students need to know that this lesson is about the passage of water and solutes in and out of plant cells.

Ensure that students understand the terms molecule, partially-permeable membrane, solution, solute and diffusion.

This simple model of osmosis does not involve consideration of the pressure from plant cell walls, nor does it show the bonding between solute and solvent. For this reason, it is inadequate as a model which predicts or explains net flow of water between solutions of different concentrations.

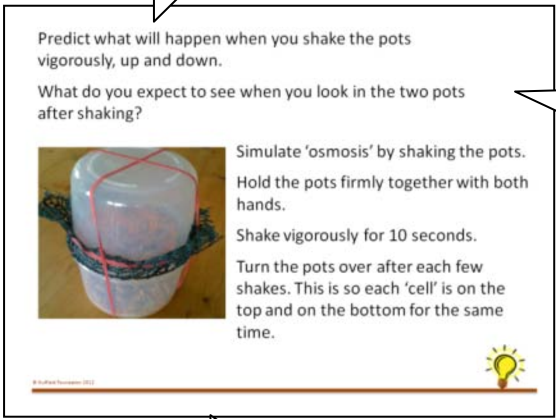
Slides 7-10



Task: Show students **slides 7–10** describing how the pot model is made.

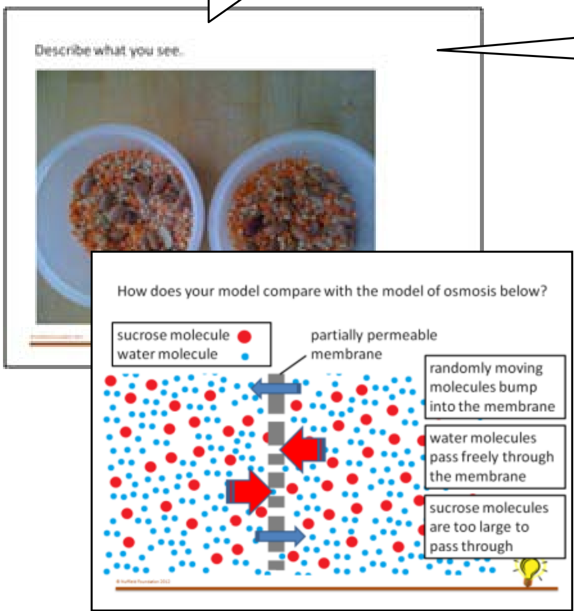
Students get into groups of four (two pairs). One pair makes a pot model to represent potato in distilled water, and the other pair makes a model to represent potato in concentrated sucrose solution.

Slide 11



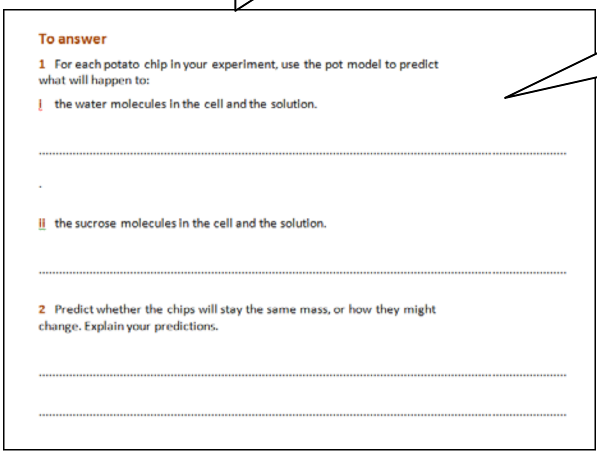
Task: Students prepare to simulate ‘osmosis’ as described on **slide 11**. The slide asks students to predict what they will see in advance of trying the model, by discussing this in their pairs. Ask some pairs to feed back to the class, and ask the students to recall what the different parts of the model represent.

Slides 12–13



Task: After shaking their models students record their findings (**slide 12**). Use **slide 13** to get students to relate their model to the diagram.

Student sheet


To answer

1 For each potato chip in your experiment, use the pot model to predict what will happen to:

i the water molecules in the cell and the solution.

ii the sucrose molecules in the cell and the solution.

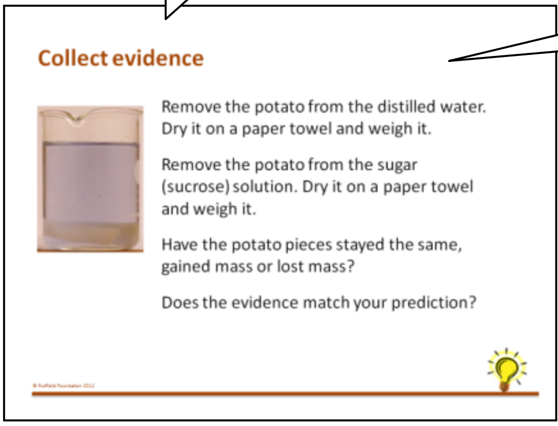
2 Predict whether the chips will stay the same mass, or how they might change. Explain your predictions.

Task: Students work in pairs to discuss and answer questions 1 and 2 on the **Student sheet**. Students should explain their prediction using scientific terms.

These questions ask students to predict the mass of the potato chips after they have been removed from the solutions. Use questions to scaffold the prediction, basing this on the pot model. For example:

- What do the different parts of the model represent?
- Predict the movement of water molecules.
- Will the sugar molecules be able to cross the membrane?

Slides 14

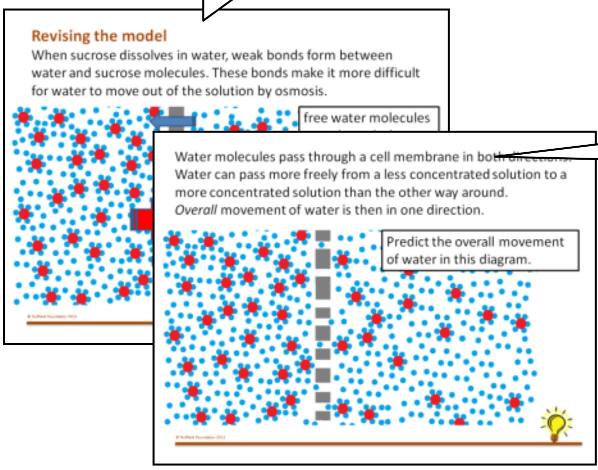


Task: Students remove the potato chips from the solutions, weigh them and record their results. Do the results match their predictions? (**slide 14**).

The 'pot model' suggests that the mass of the chips would stay the same. In fact the mass of the chip in distilled water will have increased, and the chip in sucrose solution will have decreased. The cognitive conflict arising from this difference should drive interesting discussion.

Task: Discuss which potato sample has lost mass and which has gained mass. Link the change in mass to net movement of water.

Slides 15–

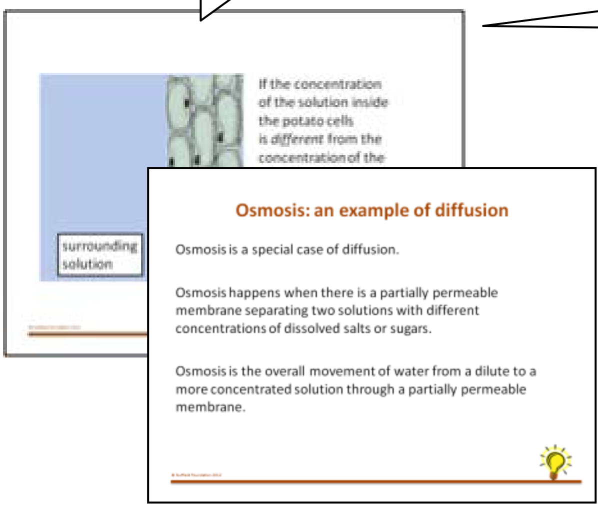


Explain: The model did not predict what actually happened and so it needs to be refined/developed.

Task: Introduce the refined model for osmosis on **slides 15 and 16**.

The 'pot model' can't account for the fact that water from a dilute solution is more likely to pass through a membrane than water from a concentrated solution. The more sophisticated diagram, showing water molecules associated with sucrose models and highlighting the idea of 'free' water, offers an explanation for the observed movement of water.

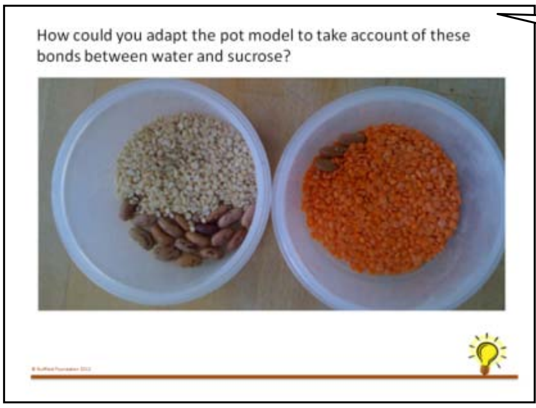
Slides 17–



Task: Students engage with the new model to explain their results. Use **slides 17 and18**.

Explanations might include that the potato piece has shrivelled up/reduced in mass. This is because more water molecules moved from the more dilute solution in the potato cells into the more concentrated sucrose solution than moved in the opposite direction. The solute molecules and water molecules form weak bonds in a solution. This means there are fewer water molecules that are free to move in and out of a cell when solute molecules are present.

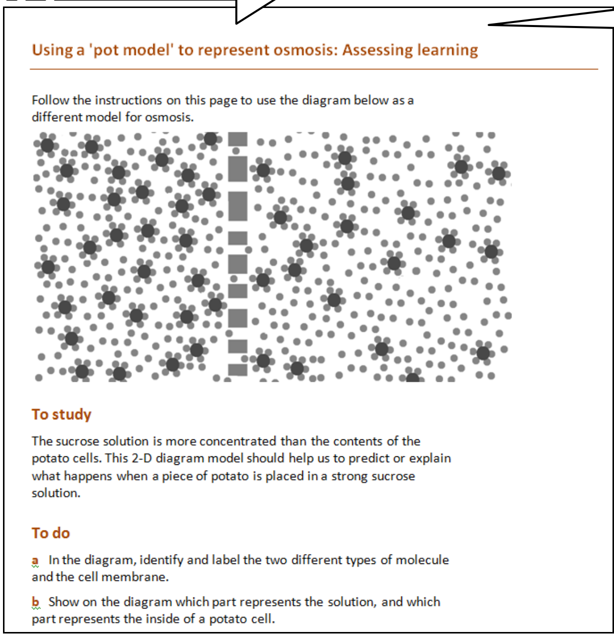
Slide 19



Task: Students work in groups of four to suggest ways in which the pot model could be improved to account for the findings (**slide 19**).

Gravity can be used to represent the pressure (diffusion gradient) produced when solutions of different concentrations are separated by a partially permeable membrane. This pressure drives the overall flow of water in osmosis. Alternatively glue or honey could be used to make the ‘sucrose’ molecules sticky before shaking, or the sucrose molecules could be represented by sticky objects such as lumps of dough or paste. If time, a ‘ready-made’ model could be demonstrated, or students could be allowed to make the refined model.

Student sheet



Using a 'pot model' to represent osmosis: Assessing learning

Follow the instructions on this page to use the diagram below as a different model for osmosis.

To study

The sucrose solution is more concentrated than the contents of the potato cells. This 2-D diagram model should help us to predict or explain what happens when a piece of potato is placed in a strong sucrose solution.

To do

a In the diagram, identify and label the two different types of molecule and the cell membrane.

b Show on the diagram which part represents the solution, and which part represents the inside of a potato cell.

Homework: Students complete the assessing learning section of the **Student sheet**.

These questions ask students to transfer their understanding to a 2-D diagram of osmosis. They are asked about how this 2-D model can be used to predict outcomes for the potato experiment, and how it can be applied to plants taking up water from the soil. This links from the model back to the observed real-world phenomenon.

Student sheet: Answers

1a The water molecules in the cell and the solution pass in both directions through the partially permeable membrane.

b The sucrose molecules cannot pass through the partially-permeable membrane and so stay in the cell, or in the solution.

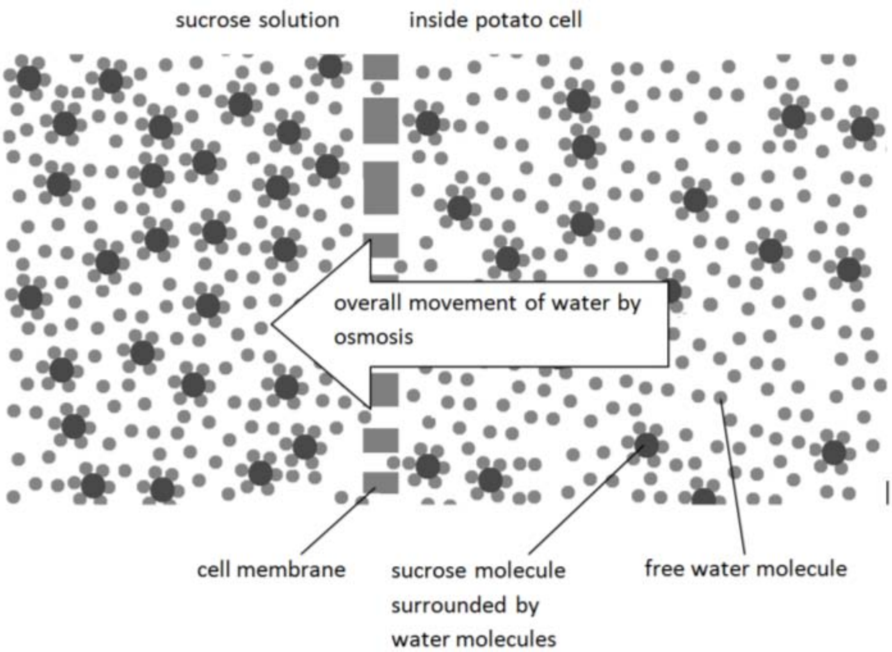
2 The chips will stay the same mass because water molecules will move in and out of the cell, but there will be no overall (net) movement of water in any one direction.

3 The mass of the chip in distilled water increased. The mass of the chip in sucrose solution decreased. (Students should then relate this to their prediction.)

4 The potato chip in distilled water increased in mass. This is because of the overall movement of water into the more concentrated solution inside the potato cells from the distilled water.

The potato chip in sucrose solution decreased in mass. This is because of the overall movement of water out of the less concentrated solution in the potato cells and into the more concentrated surrounding solution.

Assessing learning: Answers



Water moves in both directions across the partially-permeable membranes of the potato cells. The sucrose molecules can't move across the membrane.

The overall movement of water is from the cells into the more concentrated solution.

1 The model shows that the potato will lose water, so the prediction is that it will lose mass.

2 Water in the soil is less concentrated than the solution inside plant cells. The overall movement of water by osmosis is into the plant from the water in the soil.

3 Encourage students to think about how changing the model made it possible to simulate solutions with different concentrations on opposite sides of the membrane.

Using a 'pot model' to represent osmosis – Practical guidance

In **part 1,** students build a 'pot model' to represent osmosis.

In **part 2,** cut and weighed potato chips are placed in various different concentrations of sucrose solution and left for osmosis to occur. The potato chips are then removed, dried and reweighed. The percentage change in mass is calculated and/or qualitative observations are made.

Equipment and materials

Part 1 Building a 'pot model' (see note 1)

Per group/pair

Small plastic pots or beakers of equal size and shape, 2
Strong elastic bands, 3
Piece of netting large enough to be fastened over one pot (you can also use paper with holes punched in it)
Labels or pens to mark the plastic pots

Per class

Items representing water molecules (e.g. lentils) in two colours
Larger items representing sucrose molecules (e.g. large beans) in one colour

Part 2 Potato chip investigation

Per group/pair

Large baking potato
Distilled water, in wash bottle
Cork borer to cut potatoes, or potato chipper (see note 2)
Beakers (100 cm^3), 2
White tile
Knife (count these out and back in)
Ruler
Measuring cylinder (50 cm^3)
Teat pipettes, 2

Per class

Sucrose solution, 556 g / dm^{-3}; 1 litre is enough for 9 working groups
Access to balances

Health and safety and technical notes

Before carrying out this practical, users are reminded that it is their responsibility to carry out a risk assessment in accordance with their employer's requirements, making use of up-to-date information.

Read our standard health & safety guidance.

1 To make the 'pot model', you can use any small containers, such as yoghurt pots or small plastic beakers. Netting can be from vegetable/ fruit packaging, or fine garden mesh, or strong paper with holes punched in it.

Strong elastic bands are needed to hold the net in place and to hold the pots together while shaking.

The selection of items to represent the molecules will depend on the kind of netting used: one type must pass through fairly easily and the other must not pass through. The items to represent water molecules need to be available in two colours so it is clear where water has passed through the membrane (net) and in which direction.

2 Take care when cutting the potatoes. Cut onto a tile, and be prepared with first aid equipment for cuts.

A potato chipper will quickly cut chips of uniform size. It saves time if the chips are cut (using a chipper) just before or at the beginning of the lesson by a technician. Students still need to trim the chips to fit into the beaker/boiling tube.

If using a cork borer, each group (at least) should use a bore of the same diameter.

3 To simplify the investigation, cut the chips an hour before the lesson and leave them in a large bowl of water. This way they will be fully turgid at the beginning of the experiment. All the chips will then lose mass in the sucrose solutions (0% sucrose solution will stay the same).

Procedure

Part 1 Building a 'pot model'

1 Take two small pots or beakers. Label one 'cell' and the other 'surrounding solution'.

2 Choose items to represent solute molecules (e.g. sucrose), water molecules (two colours needed), and a partially-permeable membrane.

3 Put the same amount of 'water' molecules in each pot, but use a different colour in each. Add 'sucrose' molecules depending on the concentration of the solution.

4 Secure the netting to represent the membrane between the cells. Fasten the 'cells' together with elastic bands.

5 Once predictions have been made, hold the pots firmly together with both hands. Shake vigorously for 10 seconds. Turn the pots over after each few shakes, so they are each on the top and on the bottom for half the time.

Part 2 Potato chip investigation

1 Add 30 cm^3 of distilled water to a beaker and label it 'distilled water'. Add 30 cm^3 of sucrose solution to another beaker and label it 'concentrated sucrose solution'.

2 Collect two potato chips or a potato to cut up. Cut or trim your chips, if necessary to fit into your beaker. Cut off any potato skin.

3 Dry the chips on a paper towel.

4 Weigh each chip using a balance; record masses in an appropriately designed table.

5 Place one chip in each beaker. The solutions should completely cover the chips.

6 Leave for at least 15 minutes.

7 Remove chips one at a time from the beakers.

8 Dry the chips on paper towel.

9 Reweigh chips and record results in the table.

10 Calculate the change in mass of each potato chip.