REVISION GUIDE

Which way will the *water* go?

Water potential

Drop a potato core into sugar solution and it swells or shrinks, depending on which side holds more solute. Find out why water moves the way it does, what it does to cells with and without a wall, why hospitals use isotonic fluids, and at higher level how water potential puts a number on it.

8 chapters · a dry lab

The interactive guide, with every animation:

biologybybradford.com/guides/ib-biology-d2-3-water-potential

Contents

01	Why so much dissolves in water	3
02	Water goes where the solute is	5
03	Cores in sugar	7
04	No wall, no limit	10
05	The wall pushes back	12
06	Keeping cells as they are	14
07	Water runs downhill HL	16
08	ψ = ψs + ψp HL	18
	Key terms	20
	Dry lab: Cores in sugar	21
	Check yourself	23
	Answers	24

By the end you can

- [ ] Explain how water dissolves ions and polar molecules, by attraction to its charges and by hydrogen bonds D2.3.1
- [ ] Say which way water moves between two solutions in terms of solute concentration, using hypotonic, isotonic and hypertonic D2.3.2
- [ ] Predict the net movement of water into or out of a cell, and explain why there is dynamic equilibrium in an isotonic solution D2.3.3
- [ ] Measure changes in the mass and length of plant tissue in a range of solutions, and use the data, its standard deviation and standard error to find the isotonic concentration D2.3.4
- [ ] Describe what water movement does to cells without a wall, and how contractile vacuoles and isotonic tissue fluid protect them D2.3.5
- [ ] Explain turgor pressure in a hypotonic medium and plasmolysis in a hypertonic one D2.3.6
- [ ] Explain why intravenous fluids and the solutions for organs awaiting transplant are isotonic D2.3.7
- [ ] Describe water potential as the potential energy of water per unit volume, measured relative to pure water D2.3.8
- [ ] Explain why water moves from higher to lower water potential D2.3.9
- [ ] Use ψ = ψs + ψp for cells with walls, with negative solute potentials and pressure potentials that are usually positive D2.3.10
- [ ] Explain the changes in plant tissue bathed in hypotonic and hypertonic solutions in terms of solute and pressure potentials D2.3.11

Tick each one when you can do it without the book.

D2.3.1 SOLVATION WITH WATER AS THE SOLVENT

01 Why so much *dissolves* in water

A water molecule is polar: its oxygen is slightly negative (δ−) and its two hydrogens slightly positive (δ+). Drop salt into water and the molecules crowd round each ion. Round a positive ion such as Na^+ they turn their oxygens inwards; round a negative ion such as Cl^- they turn their hydrogens inwards. The attractions pull the ions out of the crystal and keep them apart. Each ion ends up wrapped in a shell of water molecules: this is **solvation**.

Polar molecules dissolve too, not by charge alone but by forming **hydrogen bonds** with water. Glucose has five −OH groups, each able to hydrogen bond, so it dissolves easily. Non-polar molecules such as fats cannot do either, so water molecules stay bonded to each other and push them out. Because so much dissolves, the cytoplasm, blood and sap are all solutions, and the dissolved particles are what make water move by osmosis.

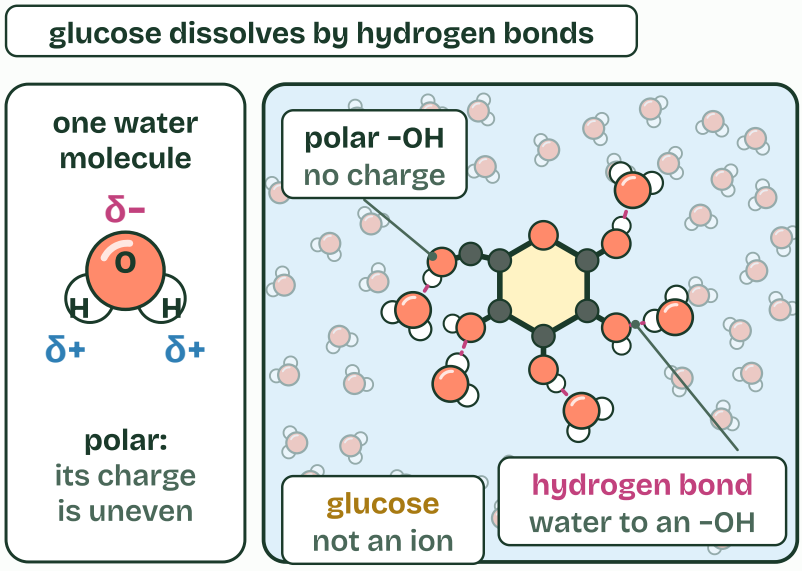
KEY POINTS

- Water is polar: δ− oxygen, δ+ hydrogens.
- Ions dissolve by attraction to the opposite charge on water.
- Polar molecules dissolve by hydrogen bonding with water.

KEY TERMS

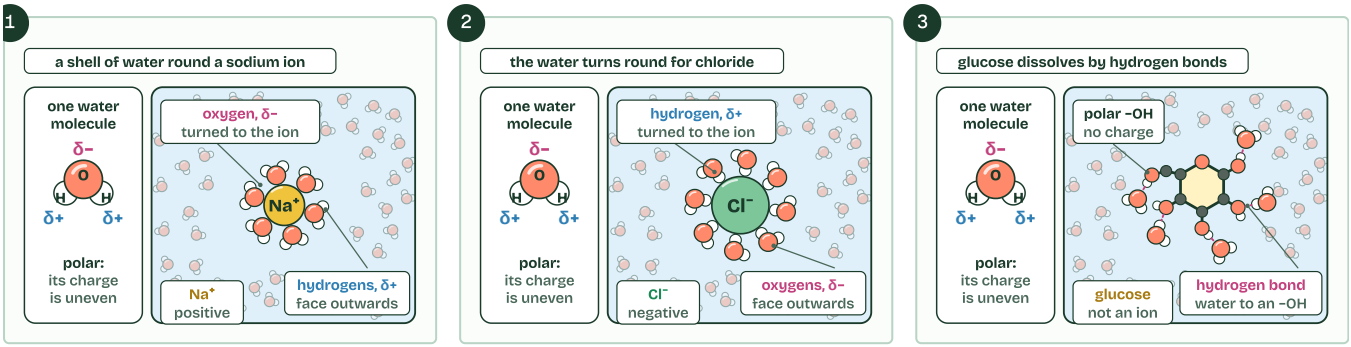
solvation
The surrounding of each dissolved ion or molecule by a shell of solvent molecules, held by attractions between their charges or by hydrogen bonds.

hydrogen bonds
A weak attraction between a slightly positive hydrogen on one molecule and a slightly negative oxygen or nitrogen on another.



STEP BY STEP

3 STEPS



A **sodium ion**, Na^+: the water molecules turn their δ− oxygens towards it.

A **chloride ion**, Cl^-: now the δ+ hydrogens face the ion.

Glucose has no charge, but its polar −OH groups form hydrogen bonds with water.

WATCH OUT

Dissolving is not a reaction. The sodium and chloride ions are unchanged, just separated and surrounded by water.

PREDICT

Which way do the water molecules round a dissolved K^+ ion face?

(A) Hydrogens inwards, because hydrogen bonds hold the ion inside the shell of water

(B) Oxygens inwards, because the δ− oxygen is attracted to the positive ion

(C) Either way at random, because the ion attracts both parts of the water molecule

Decide before you look. Answer on page 24.

D2.3.2 D2.3.3 WATER MOVEMENT FROM LESS CONCENTRATED TO MORE CONCENTRATED SOLUTIONS
WATER MOVEMENT BY OSMOSIS INTO OR OUT OF CELLS

02 Water goes where the *solute* is

Osmosis is the net movement of water across a partially permeable membrane, which lets water through but not the solute. Water molecules cross it both ways all the time. On the side with more solute, more of the water is held in shells round the dissolved particles and is less free to move, so more water crosses into the more concentrated side than comes back. The net movement is from the **less** concentrated solution to the **more** concentrated one.

To compare two solutions, use their solute concentrations. The more concentrated one is **hypertonic**, the less concentrated one **hypotonic**, and two with the same concentration are **isotonic**. A cell in a hypotonic solution gains water; in a hypertonic one it loses water. In an isotonic solution water still crosses, but as fast each way: a **dynamic equilibrium**, with no net change.

KEY POINTS

- Net water movement: from less to more concentrated solute.
- Hypotonic outside: the cell gains water. Hypertonic outside: it loses water.
- Isotonic: water still moves, equally both ways.

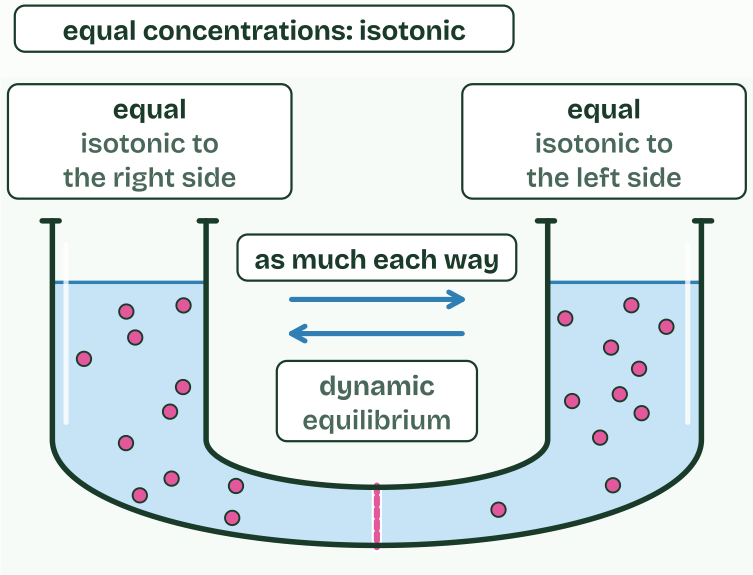
KEY TERMS

osmosis
The net movement of water across a partially permeable membrane, from a less concentrated solution to a more concentrated one.

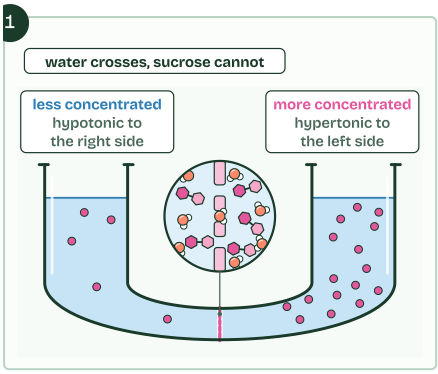
hypertonic
Having a higher solute concentration than the solution it is compared with. Water moves into a hypertonic solution.

hypotonic
Having a lower solute concentration than the solution it is compared with. Water moves out of a hypotonic solution.

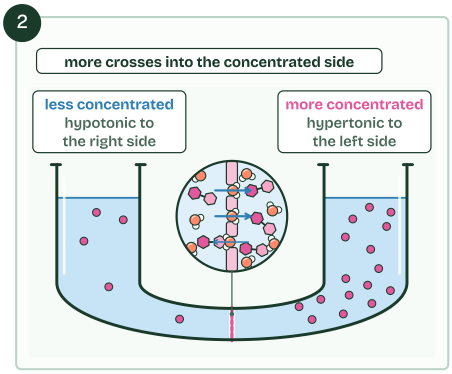
isotonic
Having the same solute concentration as the solution it is compared with, so there is no net movement of water.



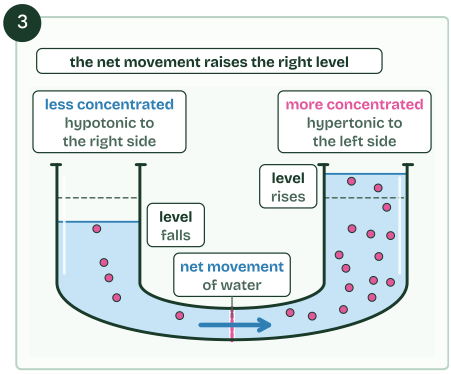
STEP BY STEP
4 STEPS



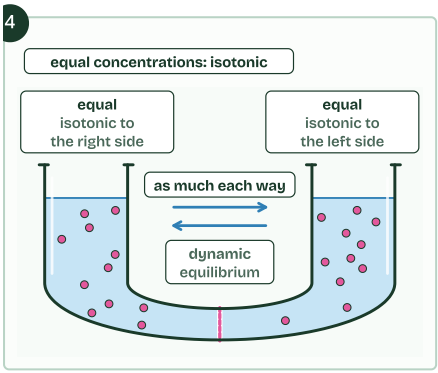
Two solutions, split by a **partially permeable membrane**. The solute cannot cross.



Water crosses **both ways**, but more crosses into the more concentrated side.



The **net** movement raises the level on the more concentrated side.



Equal concentrations, **isotonic**: water still crosses, as much each way.

WATCH OUT

Say which way water moves in terms of **solute** concentration, not "water concentration". And isotonic does not mean water stops moving.

PREDICT

A cell's cytoplasm is more concentrated than the solution around it. Which is true?

(A) The solution is hypertonic to the cell, so water moves out of the cell

(B) The solution is hypotonic to the cell, so there is a net movement of water into the cell

(C) Water stops crossing the membrane until both sides reach the same concentration

Decide before you look. Answer on page 24.

D2.3.4 CHANGES DUE TO WATER MOVEMENT IN PLANT TISSUE BATHED IN HYPOTONIC AND THOSE BATHED IN HYPERTONIC SOLUTIONS

03 Cores in *sugar*

Cut cores from a potato with a cork borer, weigh each one and measure its length, and soak them in a range of sucrose solutions. Where the solution is hypotonic to the potato's cells, they take in water: the core gains mass, gets a little longer and goes firm. Where it is hypertonic, they lose water: the core loses mass, gets shorter and goes floppy. Blot each core before weighing, so only its own water counts.

The cores start at different masses, so work out each one's **percentage change**: (final − initial) ÷ initial × 100. Plot the mean for each concentration and join the points. Where the line crosses zero, the tissue neither gains nor loses water: that concentration is **isotonic** with its cells, which is how you find their solute concentration. Repeats let you work out the **standard deviation** of each set, and from it the **standard error** of the mean, shown as error bars. Mass changes are larger than length changes and easier to measure precisely, so they usually give the clearer result.

KEY POINTS

- Hypotonic: cores gain mass. Hypertonic: cores lose mass.
- Use percentage change, so cores of different sizes compare fairly.
- The isotonic point is where the mean change crosses zero.

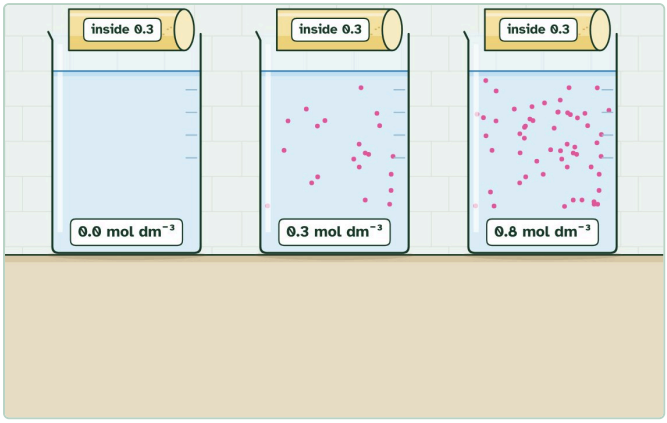
KEY TERMS

standard deviation
A measure of how spread out the repeat values are around their mean.

standard error
The standard deviation divided by the square root of the number of repeats: how precisely the mean is known. Often shown as error bars.

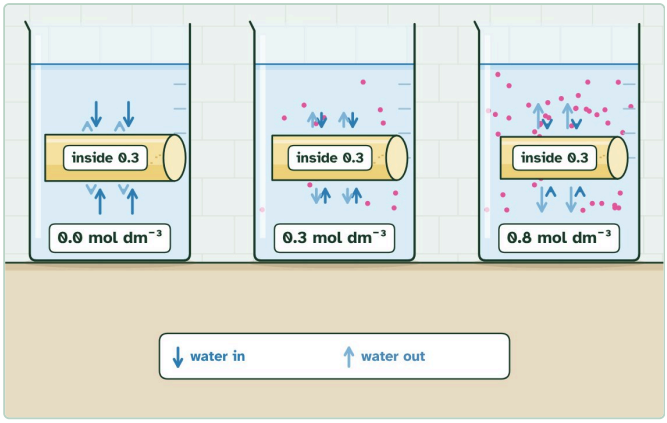
ANIMATION · INTO THE BEAKER
6 MOMENTS

1 CORES



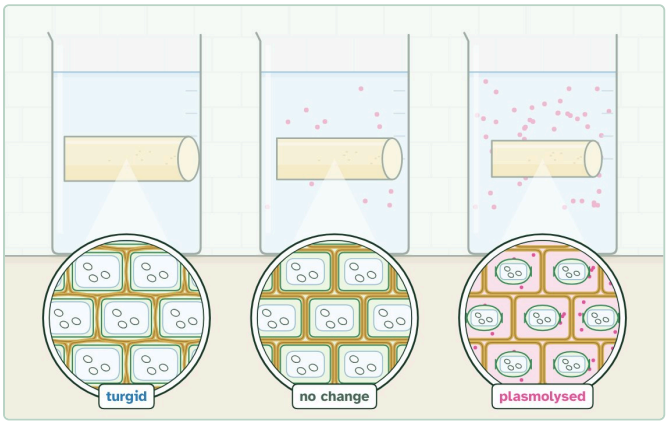
Three cores cut from one potato, 2.00 g each. Its cells hold solutes at about **0.3 mol dm⁻³**, written on each core.

2 OSMOSIS



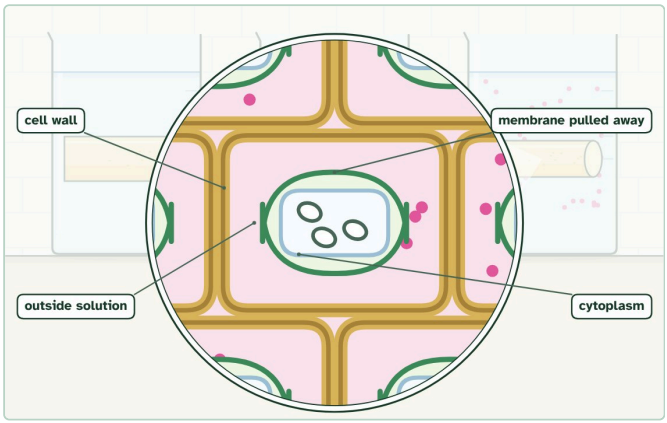
In 0.0 more water enters than leaves: the outside is **hypotonic**. In 0.8 more leaves: **hypertonic**.

3 CLOSE UP



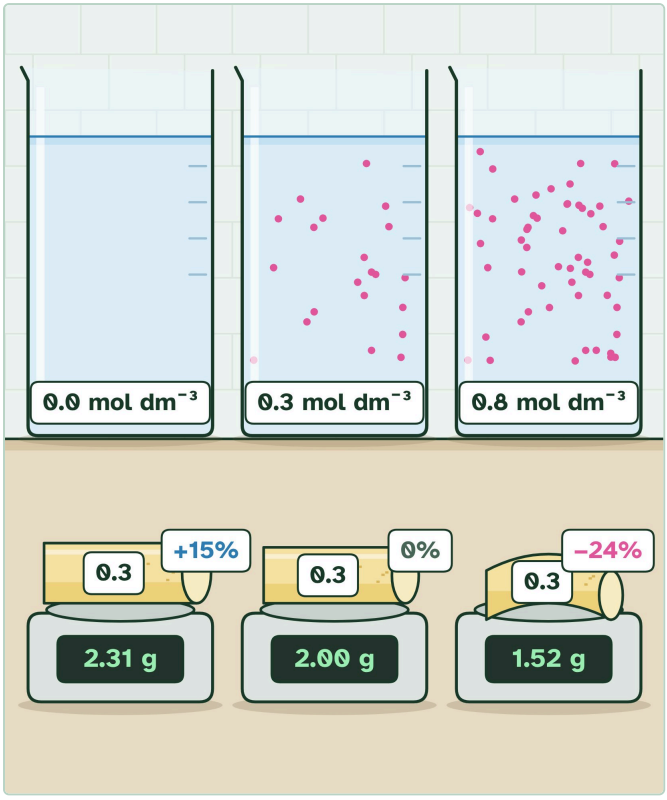
Close up: in 0.0 the cells are **turgid**, pressed against their walls. In 0.8 they are **plasmolysed**.

4 CLOSE UP



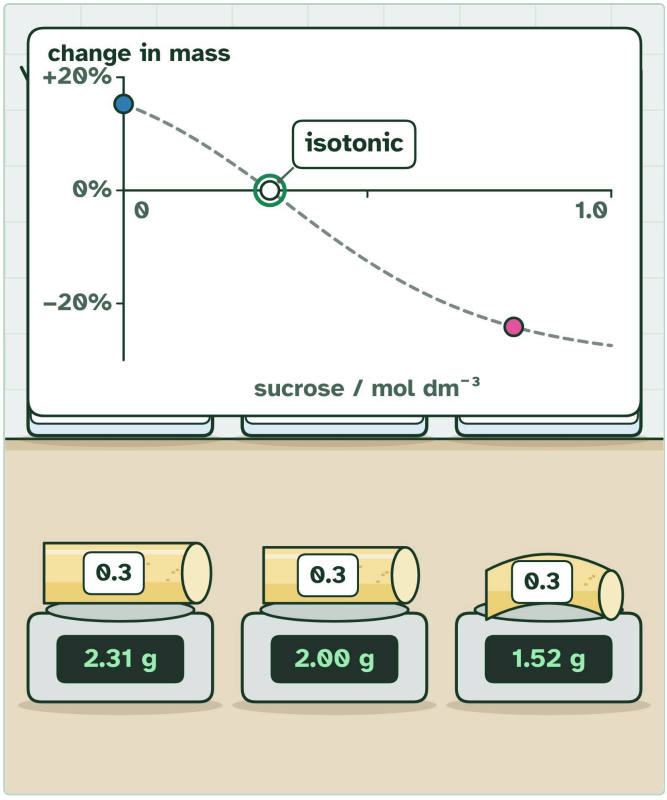
Plasmolysed: the membrane has pulled away from the wall, and the outside solution fills the gap.

5 WEIGHED



Out, blotted and weighed. The core in 0.8 has lost water and is floppy.

6 THE RESULTS



Water moves by osmosis towards the more concentrated solution. The line crosses 0% at the **isotonic** concentration. (Sizes are drawn bigger than life.)

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d2-3-water-potential#tissue

WATCH OUT

The isotonic point is rarely one of the concentrations you tested. Read it from where the line crosses zero, between two points.

PREDICT

Cores soaked in pure water gain 15% of their mass, but no more however long they are left. Why do they stop?

(A) The water outside the cores has run out of the free molecules that are able to move

(B) The cell walls push back on the swelling cells, and that pressure stops any more net water entering

(C) The cells burst after they reach 15% more mass, so they can hold no more water

Decide before you look. Answer on page 24.

04 No wall, no *limit*

D2.3.5 EFFECTS OF WATER MOVEMENT ON CELLS THAT LACK A CELL WALL

Animal cells and many single-celled organisms have only a plasma membrane round them. In a hypotonic solution they take in water and swell, and with nothing to stop them they can **burst**; red blood cells in pure water do so within seconds. In a hypertonic solution they lose water and shrink, and a red blood cell's surface puckers into points: **crenation**. Either change can stop a cell working.

Living things avoid this in two ways. Freshwater single-celled organisms such as *Paramecium* live in a hypotonic world: water enters all the time, and a **contractile vacuole** collects it and pumps it out, using ATP. Multicellular animals keep the fluid round their cells, the blood plasma and tissue fluid, isotonic with the cells, so there is no net gain or loss of water.

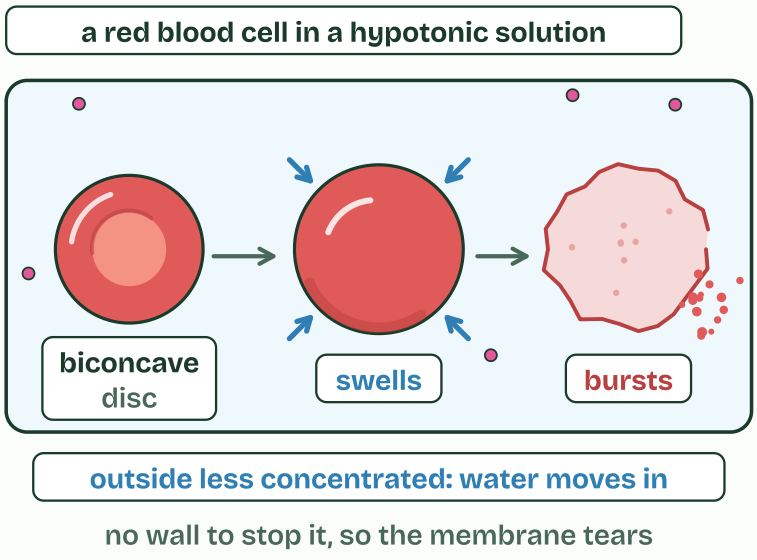
KEY POINTS

- Hypotonic: swells and may burst. Hypertonic: shrinks and crenates.
- Freshwater protists pump out the water with a contractile vacuole.
- Animals keep their tissue fluid isotonic with their cells.

KEY TERMS

crenation
The shrinking of an animal cell in a hypertonic solution, its membrane puckering into a spiky outline.

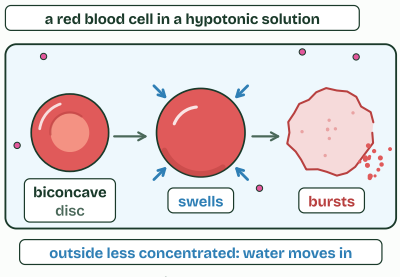
contractile vacuole
A vacuole in freshwater single-celled organisms that collects the water entering by osmosis and pumps it out of the cell, using energy.



SWITCH IT

4 SETTINGS

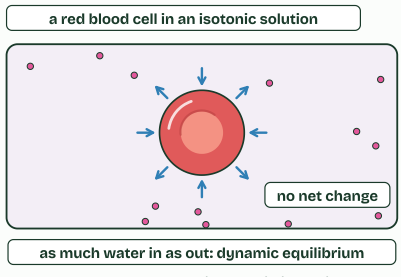
1



no wall to stop it, so the membrane tears

Hypotonic

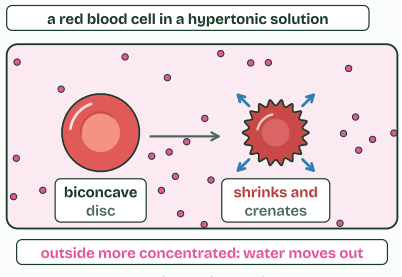
2



so the body keeps tissue fluid isotonic

Isotonic

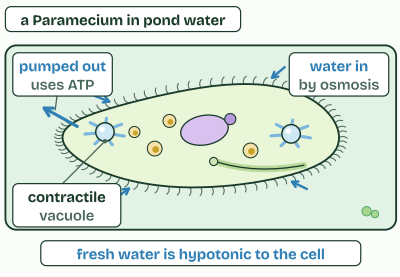
3



the cell shrivels with a spiky edge

Hypertonic

4



without its pumps a Paramecium would burst

Pond water

WATCH OUT

A contractile vacuole does not stop water coming in. It removes it as fast as it enters, and needs energy to do so.

PREDICT

A *Paramecium* is moved from pond water into a solution isotonic with its cytoplasm. What happens to its contractile vacuole?

(A) It fills and empties faster, because there is more water around the cell to deal with

(B) It fills and empties much more slowly, because water no longer enters by osmosis

(C) It goes on at the same rate, because a contractile vacuole works at a fixed pace

Decide before you look. Answer on page 24.

05 The wall *pushes back*

D2.3.6 EFFECTS OF WATER MOVEMENT ON CELLS WITH A CELL WALL

Plant cells, fungi and bacteria have a cell wall outside the membrane. In a hypotonic solution water enters, the contents swell, and the membrane presses against the wall. The wall is strong and hardly stretches, so it presses back. That pressure, **turgor pressure**, stops more water entering long before the cell could burst. Turgid cells pressing on each other keep a plant's stems and leaves firm.

In an isotonic solution the cell is **flaccid**: the membrane just touches the wall, with no pressure. In a hypertonic solution water leaves, the vacuole and cytoplasm shrink, and the membrane pulls away from the wall: **plasmolysis**. The wall is fully permeable, so the outside solution fills the gap. A plant whose cells lose turgor wilts.

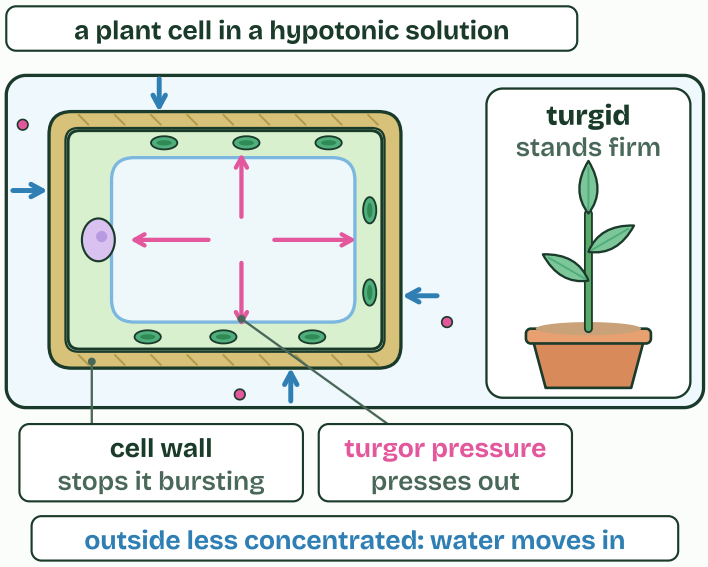
KEY POINTS

- Hypotonic: turgid; the wall resists, so the cell does not burst.
- Isotonic: flaccid, no turgor pressure.
- Hypertonic: plasmolysed; the membrane pulls away from the wall.

KEY TERMS

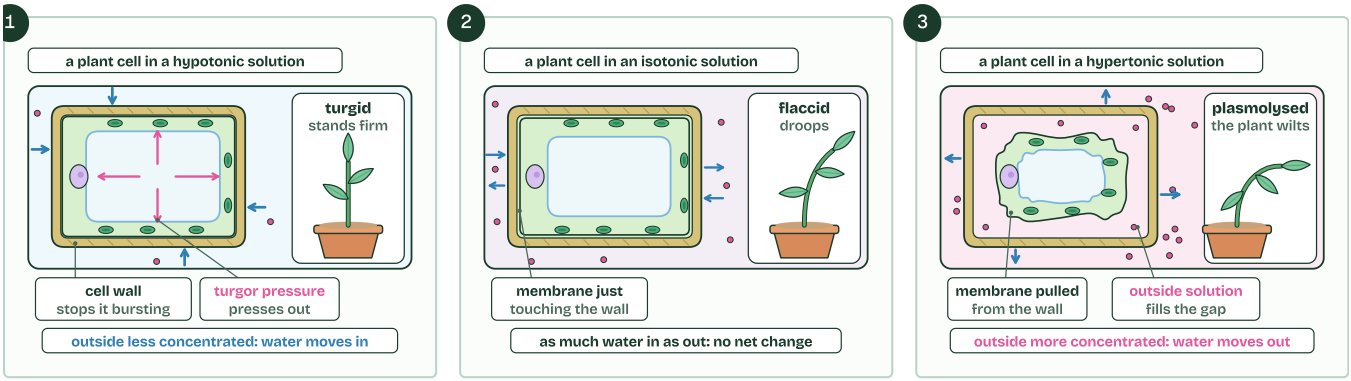
turgor pressure
The pressure of a plant cell's contents pushing out against its cell wall, built up as water enters by osmosis.

plasmolysis
The shrinking of a plant cell's contents away from its cell wall, as water leaves in a hypertonic solution.



SWITCH IT

3 SETTINGS



Hypotonic **Isotonic** **Hypertonic**

WATCH OUT

In a plasmolysed cell the gap between membrane and wall is not empty, and it is not air. It is filled with the outside solution, which passes freely through the wall.

PREDICT

Lettuce leaves left in a bowl of salty dressing go limp. Why?

(A) Salt enters the leaf cells and breaks down their cell walls, so they cannot hold their shape

(B) The dressing is hypertonic, so the cells lose water, turgor pressure falls and they become plasmolysed

(C) The dressing is hypotonic, so the cells take in so much water that they burst

Decide before you look. Answer on page 24.

06 Keeping cells *as they are*

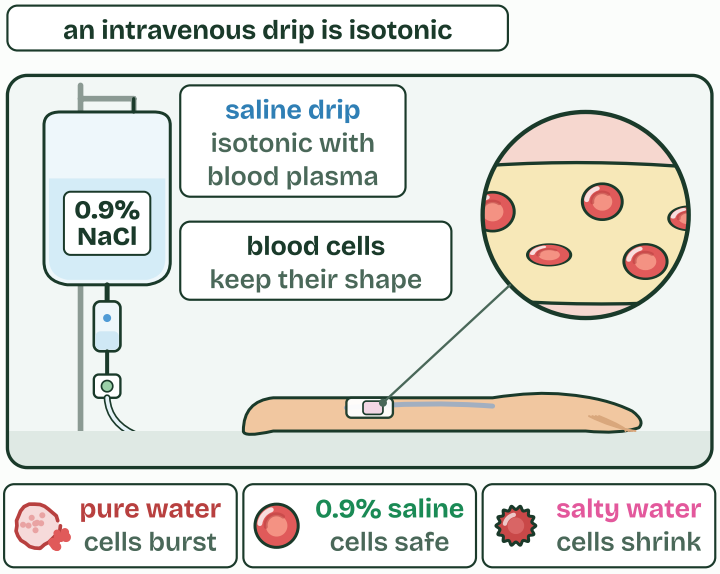
D2.3.7 MEDICAL APPLICATIONS OF ISOTONIC SOLUTIONS

Fluid put into a patient's vein runs straight into the blood, so it must be isotonic with the blood cells. **Intravenous fluids** such as normal saline, 0.9% sodium chloride, replace lost water and salts without making red blood cells swell and burst, as pure water would, or shrink, as a strong salt solution would. Some drips carry glucose at a strength that keeps them close to isotonic too.

An **organ for transplant**, such as a kidney, is taken out of the donor and kept until the patient is ready, sometimes for many hours. It is flushed and bathed in a cold isotonic solution, so its cells neither take in nor lose water. The cold slows the cells' metabolism, so they use less of the oxygen and nutrients they are no longer receiving.

KEY POINTS

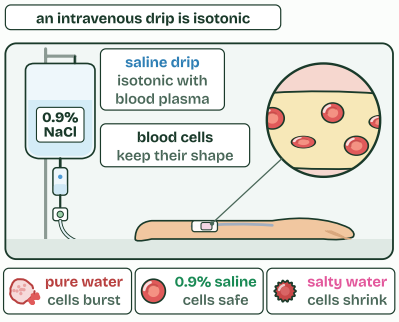
- Intravenous fluids are isotonic with blood, such as 0.9% saline.
- Donor organs are bathed in cold isotonic solution.
- Isotonic: no net water movement, so cells keep their size and shape.



SWITCH IT

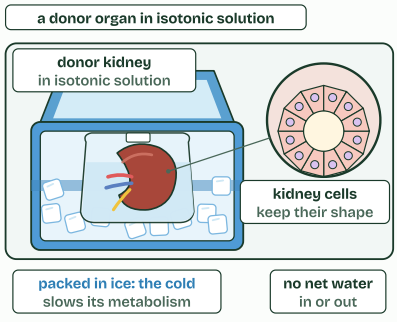
2 SETTINGS

1



Intravenous drip

2



Donor organ

WATCH OUT

Isotonic means the same solute concentration as the cells, not the same substance. Saline and a glucose drip can both be isotonic.

PREDICT

What would happen if a large volume of pure water were run into a patient's vein?

(A) Red blood cells would lose water and shrink, because pure water draws water out of cells

(B) Red blood cells would take in water by osmosis and could swell and burst

(C) Nothing would happen, because the blood's own salts would mix in with the water at once

Decide before you look. Answer on page 24.

D2.3.8 HL D2.3.9 HL WATER POTENTIAL AS THE POTENTIAL ENERGY OF WATER PER UNIT VOLUME
MOVEMENT OF WATER FROM HIGHER TO LOWER WATER POTENTIAL

07 Water runs *downhill*

Water potential, ψ (the Greek letter psi), is the potential energy of water per unit volume: how free the water is to move. Its absolute value cannot be measured, so values are given relative to a reference, pure water at atmospheric pressure and 20 °C, whose water potential is set at zero. It is measured in units of pressure, usually kilopascals (kPa).

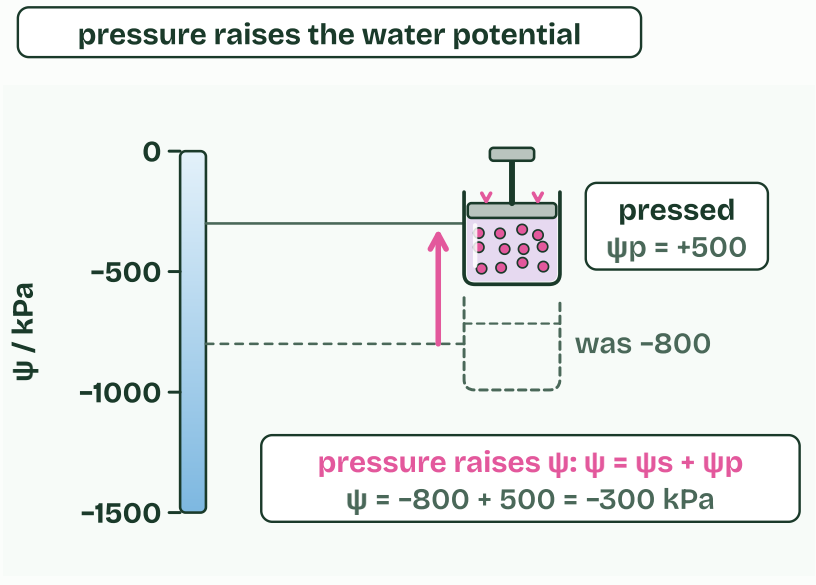
Adding solutes lowers the water potential, because water molecules held round the solutes are less free to move, so any solution has a negative ψ. Pressure raises it. Water moves from where its potential energy is higher to where it is lower, just as a ball rolls downhill: from higher water potential to lower water potential. Pure water at zero is at the top of the hill, and more concentrated solutions are further down.

KEY POINTS

- Water potential: potential energy of water per unit volume, in kPa.
- Pure water at atmospheric pressure and 20 °C: ψ = 0.
- Water moves from higher to lower ψ; solutes lower ψ, pressure raises it.

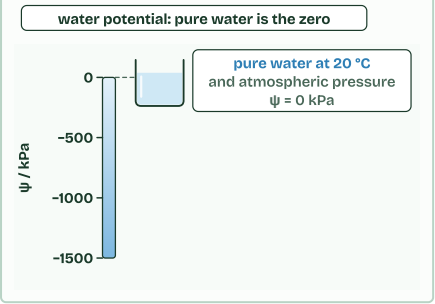
KEY TERMS

water potential
The potential energy of water per unit volume, relative to pure water at atmospheric pressure and 20 °C, which is set at zero. Symbol ψ, measured in kilopascals.



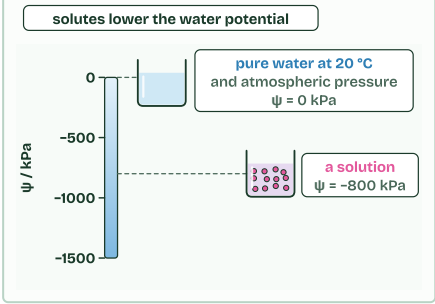
STEP BY STEP
4 STEPS

1



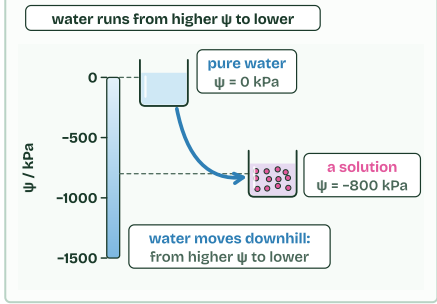
The reference: **pure water** at atmospheric pressure and 20 °C has ψ = 0.

2



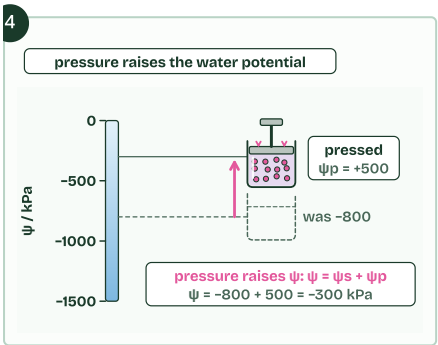
Dissolve solutes in it and its water potential falls below zero: **negative**.

3



Water moves **downhill**, from higher water potential to lower.

4



Pressure on a solution **raises** its water potential.

WATCH OUT

-800 kPa is a **lower** water potential than -300 kPa. The more negative the number, the lower the potential.

PREDICT

Cell A has a water potential of -400 kPa and cell B, next to it, -650 kPa. Which way does water move?

(A) From B to A, because 650 is the bigger number of the two values

(B) From A to B, from the higher water potential to the lower

(C) Not at all, because both cells already have negative water potentials

Decide before you look. Answer on page 24.

D2.3.10 HL D2.3.11 HL CONTRIBUTIONS OF SOLUTE POTENTIAL AND PRESSURE POTENTIAL TO THE WATER POTENTIAL OF CELLS WITH WALLS WATER POTENTIAL AND WATER MOVEMENTS IN PLANT TISSUE

08 $\psi = \psi_s + \psi_p$

In a cell with a wall, two things set the water potential. The **solute potential**, ψ_s, is zero for pure water and negative for any solution: the more solute, the more negative. The **pressure potential**, ψ_p, is the pressure of the cell's contents on its wall. It is usually positive inside cells, zero in a flaccid cell, and negative in xylem vessels, where sap is pulled up under tension. Together: $\psi = \psi_s + \psi_p$.

Put a flaccid cell with ψ_s = −800 kPa into pure water (ψ = 0). Its ψ is −800 + 0 = −800 kPa, lower than the water, so water enters. The cell presses on its wall and ψ_p rises; the solutes are diluted a little, so ψ_s rises too. Water stops entering when the cell's ψ reaches 0, with ψ_p about equal and opposite to ψ_s: the cell is turgid. Put the same cell into a solution of −1200 kPa instead and water leaves; ψ_p falls to zero, the membrane pulls away from the wall, and water goes on leaving until ψ_s has fallen to −1200 kPa: plasmolysis.

KEY POINTS

- $\psi = \psi_s + \psi_p$.
- ψ_s: zero or negative. ψ_p: usually positive in cells, negative in xylem.
- Hypotonic: ψ_p rises until ψ matches outside. Hypertonic: ψ_p falls to zero, then plasmolysis.

KEY TERMS

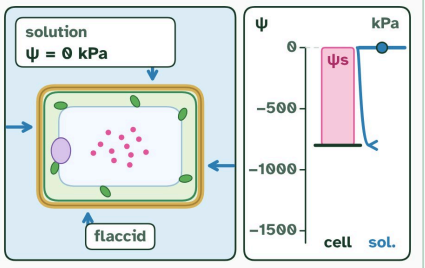
solute potential
The part of water potential due to dissolved solutes. Zero for pure water and negative for any solution.

pressure potential
The part of water potential due to pressure. Positive in a turgid cell pressing on its wall; zero in a flaccid cell; negative in xylem under tension.

ANIMATION · WATER POTENTIAL CALCULATOR

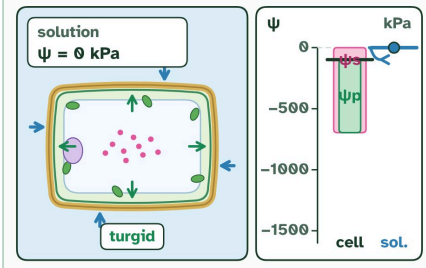
3 MOMENTS

1 START



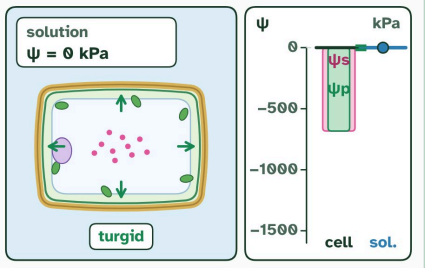
The cell: $\psi = \psi s + \psi p$ = −800 + 0 = **−800 kPa**. The solution: **0 kPa**. The solution's ψ is higher, so water moves **into the cell**, from higher to lower ψ.

2 WATER MOVING



As water enters, the protoplast pushes on the wall and ψp rises; the solutes are diluted, so ψs rises a little too.

3 EQUILIBRIUM



The wall pushes back: ψp has risen to +680 kPa, so ψ = −680 + 680 = 0 kPa, equal to the solution.

Watch it move, and change it as it runs: biologybybradford.com/guides/ib-biology-d2-3-water-potential#components

WATCH OUT

A turgid cell in pure water has a water potential of zero, not a positive one. Its high pressure potential just cancels its negative solute potential.

PREDICT

A cell has ψ_s = −900 kPa and ψ_p = +300 kPa. It is put in a solution with ψ = −750 kPa. Which way does water move?

(A) Into the cell, because its solute potential of −900 kPa is lower than the solution's

(B) Out of the cell, because its water potential, −600 kPa, is higher than the solution's

(C) Neither way, because the pressure potential stops any more water crossing the membrane

Decide before you look. Answer on page 24.

Key terms

Every term this guide defines, A to Z, with the chapter it is in. Cover the right-hand side and test yourself.

contractile vacuole 04
A vacuole in freshwater single-celled organisms that collects the water entering by osmosis and pumps it out of the cell, using energy.

crenation 04
The shrinking of an animal cell in a hypertonic solution, its membrane puckering into a spiky outline.

hydrogen bonds 01
A weak attraction between a slightly positive hydrogen on one molecule and a slightly negative oxygen or nitrogen on another.

hypertonic 02
Having a higher solute concentration than the solution it is compared with. Water moves into a hypertonic solution.

hypotonic 02
Having a lower solute concentration than the solution it is compared with. Water moves out of a hypotonic solution.

isotonic 02
Having the same solute concentration as the solution it is compared with, so there is no net movement of water.

osmosis 02
The net movement of water across a partially permeable membrane, from a less concentrated solution to a more concentrated one.

plasmolysis 05
The shrinking of a plant cell's contents away from its cell wall, as water leaves in a hypertonic solution.

pressure potential 08
The part of water potential due to pressure. Positive in a turgid cell pressing on its wall; zero in a flaccid cell; negative in xylem under tension.

solute potential 08
The part of water potential due to dissolved solutes. Zero for pure water and negative for any solution.

solvation 01
The surrounding of each dissolved ion or molecule by a shell of solvent molecules, held by attractions between their charges or by hydrogen bonds.

standard deviation 03
A measure of how spread out the repeat values are around their mean.

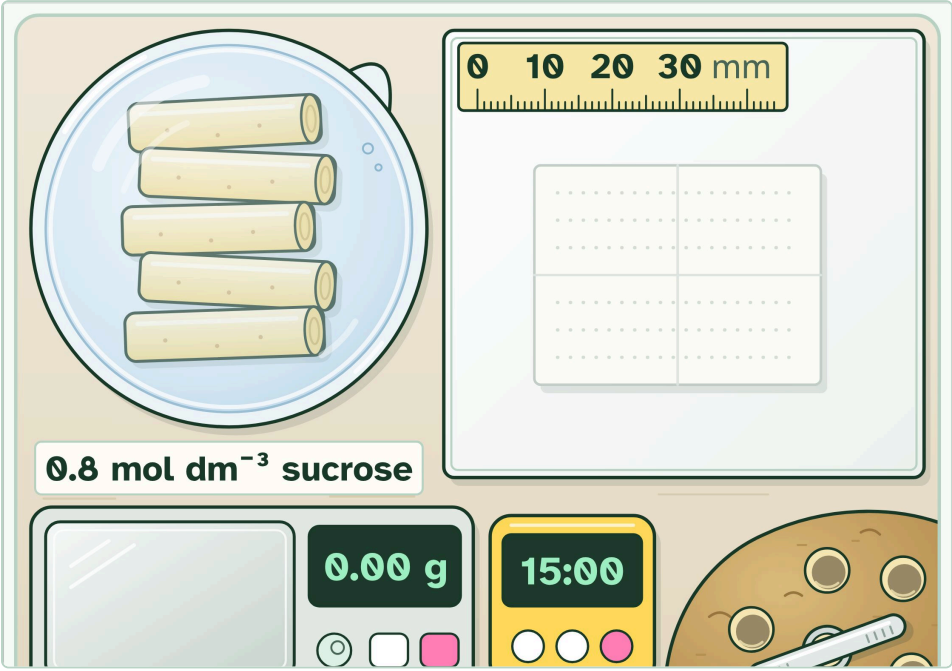
standard error 03
The standard deviation divided by the square root of the number of repeats: how precisely the mean is known. Often shown as error bars.

turgor pressure 05
The pressure of a plant cell's contents pushing out against its cell wall, built up as water enters by osmosis.

water potential 07
The potential energy of water per unit volume, relative to pure water at atmospheric pressure and 20 °C, which is set at zero. Symbol ψ, measured in kilopascals.

Dry lab: *Cores in sugar*

Cut cores of potato, sweet potato or carrot, weigh and measure them, soak them in sucrose solutions and weigh them again. Plot the percentage change, add error bars, and find the concentration where the tissue neither gains nor loses mass.



Run it online: change the variables, run the trials, and the table and graph fill in as you go. `biologybybradford.com/guides/ib-biology-d2-3-water-potential#lab`

Your question

At what concentration of sucrose does the tissue neither gain nor lose mass? That isotonic point is the solute concentration of its cells. Predict first: will a potato core gain mass in 0.2 mol dm^{-3} sucrose?

What you can change

The tissue, the sucrose concentration (0.0 to 1.0 mol dm^{-3}), and whether the cores are blotted dry before they are weighed again. Each solution gets five cores, so you have repeats for the standard deviation and standard error. Mystery colours gives six solutions of unknown concentration to rank.

What to record

The mass (to 0.01 g) and length (to 1 mm) of each core before and after 30 minutes, the percentage change in each, and for each solution the mean, standard deviation and standard error. The cores are modelled on real class results, with real scatter.

Find out

- **The potato first.** Soak cores in all six solutions, 0.0 to 1.0 mol dm⁻³. In which do they gain mass, and in which do they lose it?
- **Find the isotonic point.** Read where the line joining the means crosses 0%, type it in and check it. Then do the same for sweet potato and carrot. Which has the most concentrated cells?
- **Mass or length?** Switch on Length too. Compare the standard deviations of the two. Which measurement would you trust to find the isotonic point, and why?
- **Forget to blot.** Switch off blotting and repeat one solution. Which way does it move the result, and is the error random or systematic?

Record

- For each core: the mass and length before and after, and the percentage change: (after − before) ÷ before × 100.
- For each solution: the mean percentage change, its standard deviation and its standard error (the SD divided by the square root of the number of cores).
- A graph of mean percentage change in mass against concentration, with error bars, and the isotonic point read from it.
- In Mystery colours, the order of the six solutions from least to most concentrated, before you reveal them. Download the CSV to keep every core.

Your question At what concentration of sucrose does the tissue neither gain nor lose mass? That isotonic point is the solute concentration of its cells. Predict first: will a potato core gain mass in 0.2 mol dm⁻³ sucrose?**What you can change**The tissue, the sucrose concentration (0.0 to 1.0 mol dm⁻³), and whether the cores are blotted dry before they are weighed again. Each solution gets five cores, so you have repeats for the standard deviation and standard error. Mystery colours gives six solutions of unknown concentration to rank.**What to record**The mass (to 0.01 g) and length (to 1 mm) of each core before and after 30 minutes, the percentage change in each, and for each solution the mean, standard deviation and standard error. The cores are modelled on real class results, with real scatter.

Back to cells

Potato cores gain mass in 0.0 mol dm⁻³ sucrose and lose it in 1.0 mol dm⁻³. Explain both changes, and what the isotonic point tells you about the cells.

QUESTIONS ON THE LAB

QUESTION 1

Potato cores gain 6% of their mass in 0.2 mol dm⁻³ sucrose and lose 7% in 0.4 mol dm⁻³. What is the best estimate of the isotonic point?

(A) 0.20 mol dm⁻³, because the cores still gained mass there and so the cells must be close to it

(B) About 0.29 mol dm⁻³, where a straight line between the two points crosses zero

(C) 0.40 mol dm⁻³, because it is the first solution in which the cores lost mass overall

Answer on page 25.

QUESTION 2

Why is a percentage change in mass used rather than the change in grams?

(A) Percentages are always more precise than masses read from a balance to two decimal places

(B) The cores start at different masses, and a percentage lets them be compared fairly

(C) A percentage change cancels out any surface solution left on the cores when they are reweighed

Answer on page 25.

QUESTION 3

The error bars for 0.0 and 0.2 mol dm⁻³ overlap when they show one standard error. What can you conclude?

(A) The two solutions had exactly the same effect on the cores, so one of them can be left out

(B) The data are wrong, because bars for different concentrations should never overlap at all

(C) The difference between the two means may not be significant; more cores would help decide

Answer on page 25.

Check yourself

The check for this guide is online: a fresh paper of past-paper style questions from the exam bank on D2.3 each time, marked as you go, and saved to your Exam practice progress when you are signed in. Scan the code, or type the link.

biologybybradford.com/exam-maker/sit?topics=D2.3&level=HL&paper=quiz&marks=15&src=ep

Answers

PREDICTIONS IN THE CHAPTERS

01 Which way do the water molecules round a dissolved K^+ ion face?

B **Oxygens inwards, because the δ− oxygen is attracted to the positive ion**

Opposite charges attract. K^+ is positive, so the slightly negative oxygens face it. Round a negative ion the hydrogens would face in.

02 A cell's cytoplasm is more concentrated than the solution around it. Which is true?

B **The solution is hypotonic to the cell, so there is a net movement of water into the cell**

The solution has less solute than the cell, so it is hypotonic to it. Water moves towards the more concentrated side, into the cell. It crosses both ways throughout; only the net direction is inwards.

03 Cores soaked in pure water gain 15% of their mass, but no more however long they are left. Why do they stop?

B **The cell walls push back on the swelling cells, and that pressure stops any more net water entering**

Plant cells have walls. As water enters, the cells press against them and the walls press back. When that pressure balances the pull of the solutes, there is no more net movement in. The cells are turgid, not burst.

04 A *Paramecium* is moved from pond water into a solution isotonic with its cytoplasm. What happens to its contractile vacuole?

B **It fills and empties much more slowly, because water no longer enters by osmosis**

With no net water entering by osmosis there is little to pump out, so the vacuole slows down or nearly stops. In pond water, which is hypotonic, it has to work hard all the time.

05 Lettuce leaves left in a bowl of salty dressing go limp. Why?

B **The dressing is hypertonic, so the cells lose water, turgor pressure falls and they become plasmolysed**

Salty dressing is more concentrated than the cells. Water leaves them by osmosis, turgor pressure is lost and the cells pull away from their walls. Without turgor, the leaf has nothing to hold it stiff.

06 What would happen if a large volume of pure water were run into a patient's vein?

B **Red blood cells would take in water by osmosis and could swell and burst**

Pure water would make the plasma hypotonic to the red blood cells. Water would enter them by osmosis, and with no wall to stop it they could burst. This is why fluids for a vein are made isotonic.

07 Cell A has a water potential of −400 kPa and cell B, next to it, −650 kPa. Which way does water move?

B **From A to B, from the higher water potential to the lower**

−400 kPa is higher than −650 kPa, closer to zero. Water moves down the gradient, from A to B.

08 A cell has ψ_s = −900 kPa and ψ_p = +300 kPa. It is put in a solution with ψ = −750 kPa. Which way does water move?

B **Out of the cell, because its water potential, −600 kPa, is higher than the solution's**

Add the two: ψ = −900 + 300 = −600 kPa, which is higher than −750 kPa. Water moves down the gradient, out of the cell, and ψ_p falls as it goes. Looking at ψ_s alone gives the wrong answer.

QUESTIONS ON THE DRY LAB

Q1 Potato cores gain 6% of their mass in 0.2 mol dm⁻³ sucrose and lose 7% in 0.4 mol dm⁻³. What is the best estimate of the isotonic point?

B **About 0.29 mol dm⁻³, where a straight line between the two points crosses zero**

The change goes from +6 to −7 across 0.2 mol dm⁻³, a fall of 13 percentage points. It reaches zero 6/13 of the way along: 0.2 + 0.2 × 6/13 ≈ 0.29 mol dm⁻³. That is where the tissue neither gains nor loses water, so its cells hold solutes equal to about 0.29 mol dm⁻³ of sucrose.

Q2 Why is a percentage change in mass used rather than the change in grams?

B **The cores start at different masses, and a percentage lets them be compared fairly**

A 2.2 g core and a 1.7 g core in the same solution gain different numbers of grams but about the same fraction of their mass. Dividing by the starting mass puts every core on the same scale, so the repeats can be averaged.

Q3 The error bars for 0.0 and 0.2 mol dm⁻³ overlap when they show one standard error. What can you conclude?

C **The difference between the two means may not be significant; more cores would help decide**

Overlapping standard error bars mean the difference between the means could be due to chance variation between cores. It does not show that the effects are the same. More repeats shrink the standard error and make a real difference easier to see.

How this was made. The course structure, the activities and the teaching choices come from my own classroom, my presentations and my years of teaching IB and AP Biology. I use Claude, an AI, to help write and build the interactive guides, lesson plans, slides and practice questions, and to draw the diagrams and code the interactives. I direct the work and review it against the IB and AP specifications before it goes live.

Written and drawn for Biology by Bradford, biologybybradford.com. Free to print and share with a class.