

Supplemental Material

CBE—Life Sciences Education

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Questionnaire

1. Are you familiar with the concept of osmosis? (you can choose more than one option)

- a) NO, I see this term for the first time
- b) YES, I became familiar with it during my collage studies
- c) YES, I became familiar with it during my earlier education.

If your answer to question 1 is NO, skip to question 7.

2. In what way were you familiar with the concept?

- a) theoretical,
- b) self-conducted experiment ,
- c) observation of experiment conducted by a teacher,
- d) watching a video/animation illustrating osmosis,
- e) other (if so, what?)

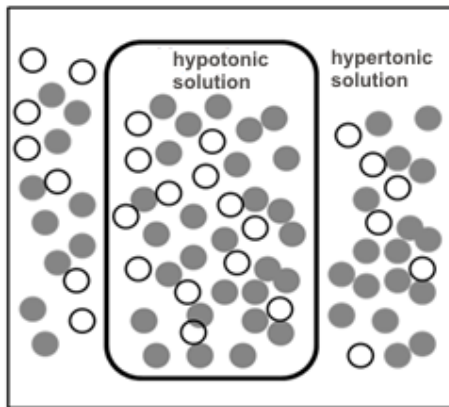
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3. If you had to explain what osmosis is, what kind of definition would you suggest?

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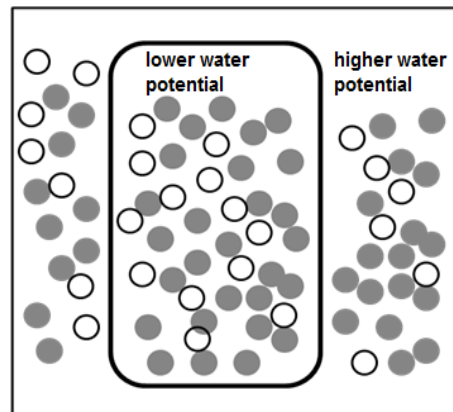
4. On the schematic picture below, point what kind of molecules move through the membrane and indicate their direction with an arrow.

a)



● water
○ dissolved substance

b)



● water
○ dissolved substance

5. What is the difference between osmosis and diffusion?

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6. Explain the concept of water potential.

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7. Are you familiar with the concept of plasmolysis?*(you can choose more than one option)*

- a) NO, I see this term for the first time
- b) YES, I became familiar with it during my collage studies
- c) YES, I became familiar with it during my earlier education.

If your answer to question 7 is NO, you don't have to fill the part of questionnaire below.

8. In what way were you familiar with the concept?

- a) theoretical,
- b) self-conducted experiment,
- c) observation of experiment conducted by a teacher,
- d) watching a video/animation illustrating osmosis,
- e) other, (if so, what?)

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9. Indicate the correct option for both processes (you can choose more than one option):

osmosis occurs in:

- a) artificial systems,
- b) plant cells,
- c) animal cells.

plasmolysis occurs in:

- a) artificial systems,
- b) plant cells,
- c) animal cells.

10. Draw a scheme of a cell located in solution of water potential:

- a) higher than water potential of cell interior,
- b) lower than water potential of cell interior.

Indicate the direction of the molecules' movement. Describe your drawings giving as much details as you can.

11. What is the connection between aquaporins and processes discussed in this questionnaire?

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12. What kind of connection can you see between the processes of plasmolysis and osmosis?

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Answer key

Question 3

If you had to explain to someone what osmosis is, what kind of definition would you suggest?

Four aspects of the answers were scored. For every aspect, on the basis of expected and students answers additional categories were developed. (see Table A1).

Elements scored :	Categories of answers:
presence of semipermeable (SM)	Yes/ No
indication of particles moving through the membrane (P).	S-solvent; W-water; L –liquid; So-solute particles; x- no indication
indication of the force that drives solvent across the semipermeable membrane (F)	C- concentration gradient; MV - molecular weight; Pr-pressure; WP-water potential, CP- chemical potential, SP-solvent potential, LP – liquid potential , XP-only “ potential “
indication of the spontaneity of the process (S)	Yes/ No

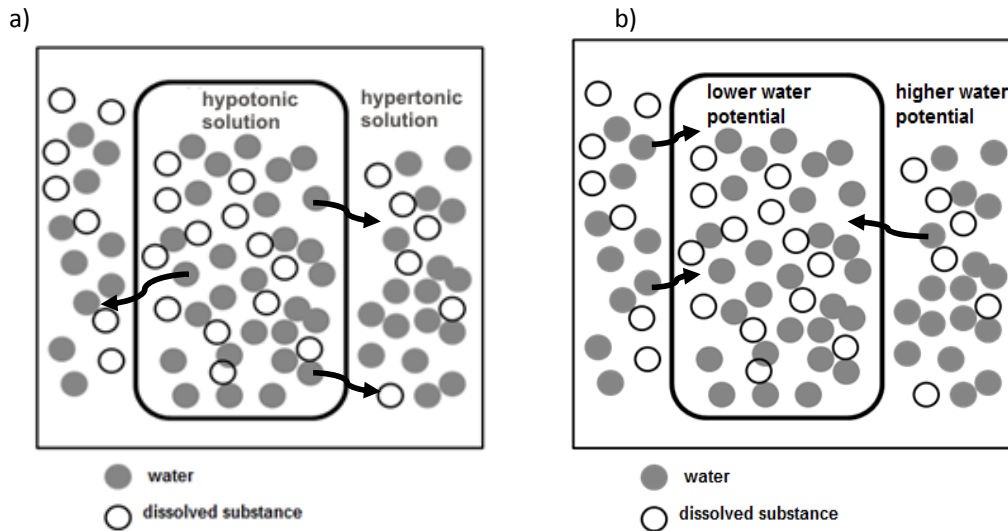
It was considered that the answer is correct if included : the presence of semipermeable membrane(SM=YES), and indication that through the membrane permeate the molecules of solvent (S). Since osmosis is mostly discussed on the example of water, the answer was also considered adequate if it contained a statement that in the osmosis process participate water (W) or liquid (L) molecules and all the other elements were taken into account properly. Indication of the force driving osmosis (F) was not obligatory but if given it had to be proper. As the correct definition of force driving osmosis water potential (WP)and chemical potential were considered (CP). Despite the fact that osmosis occurs down concentration gradient is not always true, we accept answers indicating concentration gradient as a force driving osmosis as well (C). (Kramer and Myers, 2013). After careful consideration, we also decided that indicating “the liquid potential” (LP) as a force driving osmosis would be consider as a proper.

Categories of incorrect answers:

- neglecting the presence of semipermeable membrane
- no (x) indication or indication of solute particles (So) as moving through the membrane
- no or incorrect indication of the force that drives solvent across the semipermeable membrane (MV - molecular weight; Pr-pressure)

Question 4

On the schematic picture below point out which kind of molecules move through the semipermeable membrane and indicate their direction with an arrow.



Elements scored :	Categories of answers:
Flow direction	C-correct, I –incorrect, X- no or illegible indication
Type of moving particles	W-water particles; S-solute particles, X- no or illegible

Only answers where water molecules were indicated and the direction of their movement was pointed out properly were considered as correct ones. Pictures were analysed separately.

Categories of incorrect answers:

- no/ illegible indication (x) particles moving through the membrane or indication of solute particles (S) /both solute and water particles (S,W).
- no/ illegible indication (x) incorrect indication of the flow direction.

If both elements were illegible the answer was excluded form analysis.

Question 5

What is the difference between osmosis and diffusion?

Elements scored :	Categories of answers:
Indication of difference between osmosis and diffusion	SM-presence of semipermeable membrane in osmosis process , V-different velocities, R- osmosis is reversible and diffusion not, G- osmosis refers to water / aqueous solutions, and diffusion of gases OM – osmosis refers to water osmosis and diffusion of other molecules CG - different directions of both processes in relation to the concentration gradient

	E- difference concerns the relationship of both processes of energy TM - difference is in the type of molecules permeate through the membrane DIR - difference is the direction of motion of molecules SP - difference is the size of the particles Oth- other
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The answer was considered correct if indicated that osmosis process occurs in presence of semipermeable membrane and during diffusion the membrane is usually absent (SM), pointed that osmosis occurs faster than diffusion (V) or indicate that osmosis is an reversible process while diffusion is not (R)(Kramer and Myers, 2012).

Categories of incorrect answers:

- difference concerns the relationship of both processes of energy (E)
- difference is in the type of molecules permeate through the membrane (TM)
- difference is the direction of motion of molecules (DIR)
- difference is the size of the particles (SP)
- other (Oth)

Question 6

Explain the concept of water potential.

The water potential could be described as a measure of the free energy (Gibbs energy) of water per unit volume (chemical water potential) (FE) (Jones et al., 2012) or as a sum of the pressure and the solute potential (Kramer and Myers, 2012) (S). Descriptions in the form of mathematical formulas were accepted only when mathematical symbols are described properly in the legend.

Elements scored :	Categories of answers:
Explanation of the concept of water potential.	FE –correct explanation in context of free energy S – correct explanation in context of solute potential In- incorrect answers

Categories of incorrect answers:

Due to the diversity of responses it was not possible to distinguish specific categories. All incorrect answers were included in the category – incorrect (In)

Question 9

Indicate the correct option for both processes (you can choose more than one option):

osmosis occurs in:

plasmolysis occurs in:

- a) artificial systems,
- b) plant cells,
- c) animal cells.

- a) artificial systems,
- b) plant cells,
- c) animal cells.

The correct answer was a),b), c) for osmosis and b) for plasmolysis

Question 10

Draw a schematic cell that was placed in the solution:

- a) the water potential higher than the potential of the cell interior
- b) the potential of water lower than the potential of the cell interior

Indicate the direction of water molecules movement.

Elements scored :	Categories of answers:
type of cell	P- cell Wall present, A- cell wall absent, x-illegible
change in cell turgid	C-correct, IN –incorrect, N- not included
direction of water molecules movement	C-correct, IN –incorrect, N- not included

a)

Drawing was considered correct if movement of water molecules into the cell was illustrated and if the cell diagram indicated that the cell is turgid. (For example: cell membrane adheres tightly to the cell wall or if cell lacking the cell wall was illustrated increase in cell size or break of cell membrane were pointed out)

b)

Drawing was considered correct if movment of water molecules outside the cell was illustrated and if the cell diagram indicated that the cell is flaccid (for example: plasmolyzed cell with the cell wall or shrink cell without the cell wall).

Categories of incorrect answers:

- no or incorrect indication of changes in cell turgid (C,IN)
- no indication of direction of water molecules movement (C,IN)

11. What is the connection between aquaporins and processes discussed in this questionnaire?

Elements scored :	Categories of answers:
a reference to the role of aquaporins:	Ch - membrane/ protein channels to enable the transport of water NCh - facilitate the movement of water through the membrane NM - allow the transport of water (do not include

	<p>the presence of the cell membrane)</p> <p>EC - facilitate the transport of water between the environment and the cells</p> <p>C -compounds influencing the flow of water to / from the cell</p> <p>MC - compounds involved in the maintenance of constant water potential in the cell</p> <p>OS -present at osmosis/support osmosis</p> <p>T -proteins that transport molecules of water</p> <p>IN- incorrect</p>
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The answer was considered as a correct if it highlighted the involvement of aquaporins in water flow across the cell membrane. For example aquaporins are channels facilitating water flow across cellular membranes (Ch) or aquaporins are proteins taking part in water transport through cell membrane (NCh)(Jones et al., 2012). The answers indicating water transport inside and outside the cell but not referring directly to the cell membrane (EC, C) were also considered as correct.

Categories of incorrect answers:

- no reference to a cell or cell membrane (OS, T)
- imprecise definition of the aquaporins role (MC)
- other incorrect answers do not belonging to above categories (IN)

12. What kind of connection you see between the processes of plasmolysis and osmosis?

Elements scored :	Categories of answers:
indication of the relationship between plasmolysis and osmosis	<p>EF - plasmolysis is the effect of osmosis (EF)</p> <p>(P=O)plasmolysis and osmosis is the same process</p> <p>BE -both processes rely on transport / permeation of substances between environments (no reference to the cell membrane)</p> <p>WF - both processes are related to the water flow</p> <p>C- common goal of both processes is to equalize the concentration</p> <p>P - both processes run on the same principle /are driven by the same force</p> <p>O- these processes are opposed</p> <p>Oth – other</p>

The answer had to indicate that plasmolysis results from the osmotic water flow from the cell (EF)

Categories of incorrect answers:

- indication that plasmolysis and osmosis is the same process (P=O)
- indication that both processes rely on transport / permeation of substances between environments (no reference to the cell membrane) (BE)
- indication that both processes are related to the water flow (WF)

- indication that common goal of both processes is to equalize the concentration (C)
- indication that both processes run on the same principle /are driven by the same force (P)
- indication that these processes are opposed (O)
- other (Oth)

High school textbooks used for qualitative analysis:

- 1) Balerstet J, Lewiński W, Prokop J, Sabath K, Skirmuntt G, Holak E, Łaszczycza A, Walkiewicz J, Bartnik E. Biology textbook, advanced level, Publishing Operon, Gdynia 2008
- 2) Batko A. Botany and Cell Biology, Publishing Prószyński i S-ka, Warsaw 2000
- 3) Czubaj A (Eds.) Biology textbook, advanced level, Publishing WiSP, Warsaw 2003,
- 4) Duszyński J, Grykiel K, Hryniewiecka L, Jarmołowski A, Błoszyk J, Jackowiak B, Lesicki A, Ratajczak L, Godzińska EJ, Kaszycka KA, Ryszkiewicz M, Kozłowska – Rajewicz A, Krenz-Niedbała M, Ziemnicki K. Biology textbook, advanced level, Publishing PWN, Warsaw 2007
- 5) Wiśniewski H. Biology textbook, advanced level, Publishing Agmen, Warsaw 2003,

Academic textbooks used for qualitative analysis:

- 1) Alberts B, Bray D, Hopkin K, Johnson A, Lewis J, Raff M, Roberts K. Basics of cell biology. Publishing PWN, Warszawa 2005
- 2) Campbell NA, Reece JB (Eds.) Biology. Publishing Dom Wydawniczy Rebis, Poznan 2012
- 3) Kopcewicz J, Lewak S (Eds.) Plant Physiology. Publishing PWN, Warsaw 2012
- 4) Kozłowska M (Eds.) Plant Physiology. Publishing Państwowe Wydawnictwo Rolnicze i Leśne, Poznan 2007
- 5) Maćkowiak M, Michalak A (Eds.) Biology. Unity and diversity, Publishing PWN, Warsaw 2008
- 6) Solomon E, Berg L, Martin D, Ville C. Biology. Publishing Multico Oficyna Wydawnicza, Warsaw 1996.
- 7) Szweykowska A. Plant Physiology. Publishing Wydawnictwo Naukowe UAM, Poznań 2000
- 8) Woźny A, Michejda J, Ratajczak L (Eds.) Basics of plant cell biology. Publishing Wydawnictwo Naukowe UAM, Poznan 2001