

Biology > Big idea BCL: The cellular basis of life > Topic BCL1: Cells

Key concept (age 11-14)

BCL1.4: Diffusion and the cell membrane

What's the big idea?

A big idea in biology is that organisms are made of one or more cells.

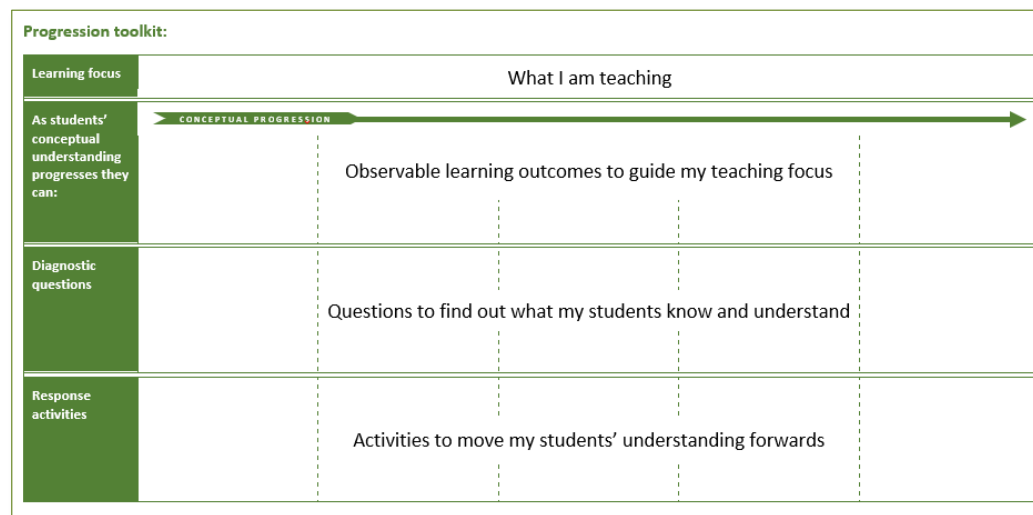
How does this key concept develop understanding of the big idea?

This key concept helps to develop the big idea by developing students' understanding of how the substances that cells need (and need to get rid of) in order to stay alive move into, out of, within and between cells.


The conceptual progression starts by checking understanding of the role of the cell membrane in supporting the life processes of cells. It then supports the development of particle-level explanations of diffusion in the cell cytoplasm and diffusion through the selectively permeable cell membrane.

Using the progression toolkit to support student learning

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.



Progression toolkit: Diffusion and the cell membrane

Learning focus	Molecules move through the cell cytoplasm by diffusion, and some molecules can enter and leave a cell by diffusing through the cell membrane.										
As students' conceptual understanding progresses they can:											
As students' conceptual understanding progresses they can:	Use ideas about the needs and life processes of cells to explain the role of the cell membrane and why it must be selectively permeable.	Recall that substances are made of particles that move and collide randomly all the time.	Explain diffusion as the net movement of particles from an area of their higher concentration to an area of their lower concentration.	Explain the diffusion of particles through a selectively permeable membrane.	Apply ideas about diffusion through the cell membrane to explain why some cells have a larger surface area. B						
Diagnostic questions	<table border="1" style="width: 100%;"> <tr> <td style="width: 50%;">The right structure for the job</td> <td style="width: 50%;">Across the membrane</td> </tr> <tr> <td>The cell membrane</td> <td>In and out of a cell</td> </tr> <tr> <td></td> <td>Dead cell</td> </tr> </table>	The right structure for the job	Across the membrane	The cell membrane	In and out of a cell		Dead cell	Cytoplasm – a particle model	Deodorant		Root hair cell
The right structure for the job	Across the membrane										
The cell membrane	In and out of a cell										
	Dead cell										
Response activities	<table border="1" style="width: 100%;"> <tr> <td style="width: 50%;">Match game! The role of the cell membrane</td> <td style="width: 50%;">Modelling diffusion</td> </tr> <tr> <td>What does the cell membrane look like?</td> <td>PEOE – Dye in water</td> </tr> </table>	Match game! The role of the cell membrane	Modelling diffusion	What does the cell membrane look like?	PEOE – Dye in water	Drawing cytoplasm		PEOE – A cup of tea			
Match game! The role of the cell membrane	Modelling diffusion										
What does the cell membrane look like?	PEOE – Dye in water										

Key:

B Bridge to later stages of learning

What's the science story?

Organisms, living and dead, are made up of cells. All cells are made up of common parts, including cytoplasm contained by a cell membrane, and these parts have common functions in all cells. To stay alive, cells need a constant supply of energy and molecules for chemical reactions, and they need to get rid of waste. Molecules move through the cytoplasm by diffusion, and some molecules can enter and leave a cell by diffusing through the cell membrane.

All matter is made up of particles. The arrangement and movement of these particles is described by the particle model.

What does the research say?

Cells and diffusion

Dreyfus and Jungwirth (1988) found that many 16-year-olds struggled to explain how cells carry out life processes; many of the students thought that cells contain macroscopic organs such as a digestive tract (e.g. for nutrition) or lungs (e.g. for respiration). This could be related to the misunderstanding that substances such as oxygen and food/glucose are taken into cells by breathing or eating, respectively, rather than by diffusion through the cell membrane (Allen, 2014). Incorrect animistic and anthropomorphic views were also commonly observed in students, including the belief that cells and organelles have desires and intentions (e.g. they 'know' or 'want' to take in and discard particular substances). These beliefs may be introduced or reinforced by the use of cartoon-like depictions of cells and organelles with faces (which create misunderstandings about the size and scale of cells relative to organs) or with speech/thought bubbles (implying that they can think).

Various researchers (Odom, 1995; Tomažič and Vidic, 2012; Stains and Sevian, 2015; Oztas and Oztas, 2016) have used diagnostic questions to reveal common misunderstandings about diffusion in school children that can persist in students up to university level, including that:

- molecules in an area of high concentration want to spread out, or move to seek out an area with more room;
- molecules move only in one direction, from an area of higher concentration to an area of lower concentration (a failure to understand the random movement of particles versus the concept of *net* movement);
- movement of particles stops after the concentration gradient between two areas has been equalised by diffusion (possibly because students interpret "no net movement" to mean "no movement of particles");
- diffusion of a substance through a solvent requires a chemical reaction, or occurs because the substance splits up into smaller bits that mix with the solvent
- diffusion requires energy from a cell, and would stop if the cell died.

Some students believe that diffusion requires an external force or mechanical event (rather than resulting from the intrinsic movement of particles), a misunderstanding that may be linked to students' everyday experiences of stirring and dissolving, such as stirring sugar into tea (Çalýk, Ayas and Ebenezer,

2005; Stains and Sevian, 2015). There may be confusion between the scientific and everyday meanings of terms such as “concentration” (Odom and Barrow, 1995).

A number of researchers (Christianson and Fisher, 1999; Sanger, Brecheisen and Hynek, 2001; Meir et al., 2005; Krajšek and Vilhar, 2010; Haddad and Baldo, 2010; Winterbottom, 2011; Wilkerson-Jerde, Gravel and Macrander, 2015; Kutzner and Pearson, 2017) have described constructivist approaches that enable students to build their own explanations of diffusion, which may help to develop students’ understanding and overcome misconceptions, including for example:

- group discussion, both teacher-led and student-student;
- challenging students to apply concepts they have been taught to make predictions;
- asking students to create and use models to explain diffusion at the particle level, including drawings, animations, computer simulations, physical models (e.g. sieves and balls), and role-play.

Particle explanations

Explaining diffusion requires a secure understanding of concepts from chemistry and physics, including the particulate nature of matter and the behaviour of particles in solutions. Students can struggle to understand and explain diffusion because of the interdisciplinary nature of the topic (Tekkaya, 2003; Odom, 2007), because of the need to visualise and think about processes at the molecular level (Sanger et al., 2001), and because of the apparent disconnect between what happens at the macroscopic level and what happens at the particle level – e.g. molecules collide and move in random directions and do not stop, but there is net movement from high concentration to low concentration until equilibrium is reached (AlHarbi et al., 2015; Stains and Sevian, 2015).

Several studies have reported that children aged 11-16 lack an appreciation of size and scale, manifested in their assumption that atoms, molecules and cells are all the same size. This conflation has been dubbed “the molecell” (Arnold, 1983). Some children would only apply the term “molecule” to things they had studied in chemistry and physics (Dreyfus and Jungwirth, 1988).

Johnson (1998) summarises research in which it was found that students have various ways of thinking about substances and what they are made up of at the sub-microscopic level, including:

- that substances are continuous and are not made up of (or do not contain) particles (incorrect);
- that there are particles *in* the continuous substance – i.e. the substance is between the particles (incorrect);
- that particles *are* the substance – i.e. the substance is made up of particles (correct).

Those students who did talk about particles showed very little appreciation of the intrinsic, random movement of particles.

Guidance notes

Explaining diffusion requires a secure understanding of concepts from chemistry and physics, including the particulate nature of matter and the behaviour of particles in solutions. Understanding of those concepts is tested as part of the progression toolkit for this key concept, but a fuller range of diagnostic questions and response activities to probe and develop students' understanding are provided in the following BEST key concepts, which could be regarded as pre-requisites:

- Key concept: CPS1.1 *Particle model for the solid, liquid and gas states*
- Key concept: CPS1.2 *Particles in solutions*

Odom (1995) has defined a list of knowledge statements required for understanding diffusion in the context of cells, including:

1. All particles are in constant motion.
2. Diffusion involves the movement of particles.
3. Diffusion results from the random motion and/or collisions of particles (ions or molecules).
4. Diffusion is the net movement of particles as a result of a concentration gradient.
5. Concentration is the number of particles per unit volume.
6. Concentration gradient is a difference in concentration of a substance across a space.
7. Diffusion is the net movement of particles from an area of high concentration to an area of low concentration.
8. Diffusion continues until the particles become uniformly distributed in the medium in which they are dissolved.
9. Diffusion occurs in living and non-living systems.
10. A selectively permeable membrane is a membrane that allows the movement of some substances across the membrane while blocking the movement of others.
11. Cell membranes are selectively permeable.

References

AlHarbi, N. N. S., et al. (2015). Influence of particle theory conceptions on pre-service science teachers' understanding of osmosis and diffusion. *Journal of Biological Education*, 49(3), 232-245.

Allen, M. (2014). *Misconceptions in Primary Science*, Second edn Berkshire, UK: Open University Press.

Arnold, B. (1983). Beware the molecell! *Biology Newsletter*, 42, 2-6.

Çalýk, M., Ayas, A. and Ebenezer, J. V. (2005). A review of solution chemistry studies: insights into students' conceptions. *Journal of Science Education and Technology*, 14(1), 29-50.

- Christianson, R. G. and Fisher, K. M. (1999). Comparison of student learning about diffusion and osmosis in constructivist and traditional classrooms. *International Journal of Science Education*, 21(6), 687-698.
- Dreyfus, A. and Jungwirth, E. (1988). The cell concept of 10th graders: curricular expectations and reality. *International Journal of Science Education*, 10(2), 221-229.
- Haddad, H. and Baldo, M. V. C. (2010). Teaching diffusion with a coin. *Advances in Physiology Education*, 34(3), 156-157.
- Johnson, P. (1998). Progression in children's understanding of a basic particle theory: a longitudinal study. *International Journal of Science Education*, 20(4), 393-412.
- Krajšek, S. S. and Vilhar, B. (2010). Active teaching of diffusion through history of science, computer animation and role playing. *Journal of Biological Education*, 44(3), 116-122.
- Kutzner, M. and Pearson, B. (2017). A student diffusion activity. *Physics Teacher*, 55(2), 109-111.
- Meir, E., et al. (2005). How effective are simulated molecular-level experiments for teaching diffusion and osmosis? *Cell Biology Education*, 4(3), 235-248.
- Odom, A. (1995). Secondary & college biology students' misconceptions about diffusion & osmosis. *The American Biology Teacher*, 57(7), 409-415.
- Odom, A. (2007). High school biology students' knowledge and certainty about diffusion and osmosis concepts. *School Science and Mathematics*, 107(3), 94-101.
- Odom, A. L. and Barrow, L. H. (1995). Development and application of a two-tier diagnostic test measuring college biology students' understanding of diffusion and osmosis after a course of instruction. *Journal of Research in Science Teaching*, 32(1), 45-61.
- Oztas, F. and Oztas, H. (2016). How do biology teacher candidates know particulate movements & random nature of matter and their effects to diffusion. *Journal of Education and Practice*, 7(29), 189-194.
- Sanger, M. J., Brecheisen, D. M. and Hynek, B. M. (2001). Can computer animations affect college biology students' conceptions about diffusion and osmosis? *The American Biology Teacher*, 63(2), 104-109.
- Stains, M. and Sevian, H. (2015). Uncovering implicit assumptions: a large-scale study on students' mental models of diffusion. *Research in Science Education*, 45(6), 807-840.
- Tekkaya, C. (2003). Remediating high school students' misconceptions concerning diffusion and osmosis through concept mapping and conceptual change text. *Research in Science & Technological Education*, 21(1), 5-16.
- Tomažič, I. and Vidic, T. (2012). Future science teachers' understandings of diffusion and osmosis concepts. *Journal of Biological Education*, 46, 66-71.
- Wilkerson-Jerde, M. H., Gravel, B. E. and Macrander, C. A. (2015). Exploring shifts in middle school learners' modeling activity while generating drawings, animations, and computational simulations of molecular diffusion. *Journal of Science Education and Technology*, 24(2), 396-415.
- Winterbottom, M. (2011). Transport in organisms. In Reiss, M. (ed.) *ASE Science Practice: Teaching Secondary Biology*. London, UK: Hodder Education.