Introduction

Within every academic discipline there appears to be certain concepts that learners will struggle with. This has led to the idea of threshold concepts, concepts within disciplines that offer unique challenges to the learner (threshold concepts are transformative in that they change the way a student views the subject, as well as liminal meaning the journey to understanding is seldom straightforward and instead is fraught with misunderstandings) (Meyer & Land, 2005). For Biology one of those concepts identified as problematic by both students and teachers is osmosis (Griffiths & Preston, 1992; Odom & Barrow, 1995; Ross et al., 2010; Taylor, 2010). When tackling a troublesome concept it might be necessary to go back to the basics, and employ multiple teaching and learning approaches such as inquiry-based learning, identifying misconceptions, scaffolding and co-operative learning to help students engage with and understand the problem. The rationale for the choice of these strategies will be developed in the ensuing discussion.

What is osmosis and why is it problematic?

Osmosis appears to be counter-intuitive to many students, while they can give the definition of what osmosis is, when given an osmotic problem they are unable to solve it. For some students, moving from knowing a definition to understanding the theory that the definition explains, before finally being able to apply that theory is not a straightforward linear progression (Biggs, 2003).
For osmosis it may be because it truly is counter-intuitive or it may simply be because osmosis definitions can be worded differently as osmosis is a relative comparison. For example below are two definitions of osmosis:

a) the movement of water from low solute concentration to high solute concentration through a semi-permeable membrane
b) the movement of water from high water potential to low water potential through a semi-permeable membrane

In a) the focus is on solute concentration, while b) the focus is on water potential. Osmosis is described both ways and if a student fails to truly grasp what is occurring during osmosis it is easy to see how these definitions seem confusing. In addition other key terms of hypo- hyper- or isosmotic can be flipped around due to the relative nature of the terms. For example when describing an osmotic experimental set up using a marine annelid worm (Nereis sp.), it is possible to describe the same set up in two different ways:

c) The Nereis is hyper-osmotic to its environment.
d) The environment is hypo-osmotic to the Nereis.

Again the importance of the terminology being relative is apparent, and this is certainly an area students struggle with. Even students who demonstrate a good understanding of osmosis struggle to use the new terminology correctly, but it is crucial that the words are used correctly or the completely wrong meaning is conveyed. This can be seen in the following test question and typical answers (taken from BIOL101 test question, 2013).

*What would happen to a red blood cell (1.8% NaCl) if it was placed in to a solution*
of 1% saline? Explain your answer in terms of water movement.

The cell would burst, because the concentration is lower and therefore hyposmotic.

The cell would burst, because water moves towards a high concentration

In the above example, what we see is the correct answer but an incomplete and confusing explanation. As a marker I would be able to see that the student likely was on the right track because indeed the cell would burst (due to an influx of water) but the student has failed to explain the relative aspects of the situation. In both answers it is unclear what concentration they are referring to as it could be solute concentration, or water concentration (see definitions for osmosis a and b). They also fail to say what is hypo-osmotic (see c and d). An ideal answer would be that the cell bursts because it is placed in to a hypo-osmotic environment, causing water to enter the cell as water moves towards the higher solute concentration.

Without an understanding of osmosis students cannot progress to understand some of the fundamental topics in biology. For example an understanding of how an animal regulates its internal solute concentration is important for any biologist because it can be applied across all animals to varying levels of complexity. Osmosis is a key component of photosynthesis, cell membrane transport and nerve conduction. Osmosis is integrative, once a student truly understands the mechanisms behind it they can bring together seemingly unrelated areas of biology and see connections (Meyer & Land, 2005).
Teaching and Leaning Strategies to Support Students’ Understanding of a Difficult Concept

A number of strategies and approaches have been selected to try and improve student understanding of osmosis. These include the use of diagnostics, inquiry-based learning, scaffolding and co-operative learning. The text will address each of these areas and explain the rationale for these choices.

Using Diagnostics to Identify Misconceptions and Knowledge

When students fail to achieve the results that educators expect there is often a number of reasons given such as students find the topic boring and difficult, they do not work hard enough, or they are ill-prepared for class (Martin-Blas, Seidel, Serrano-Fernandez, 2010; Prosser & Trigwell, 1999). One area that should be taken in to account is students’ existing knowledge which might be scientifically inconsistent and deeply entrenched making it difficult to change (Martin-Blas, et al., 2010; Odom & Barrow, 1995). Incorrect science knowledge may come in the form of preconceptions, naïve beliefs, intuitive beliefs, alternative frameworks or misconceptions (Griffiths & Preston, 1992). For the remainder of this report misconceptions will be used to encompass these incorrect ideas, using the Cho, Kahle and Norland (1995, cited in Griffiths & Preston, 1992) definition of misconceptions as “any conceptual idea whose meaning deviates from the one commonly accepted by scientific consensus.”

There are a multitude of ways to identify misconceptions including conducting student interviews, concept maps and diagnostic testing (Fisher, Williams & Lineback, 2011; Martin-Blas et al., 2010; Odom & Barrow, 1995; Treagust, 1988). As with any method, each has its strength and weakness such as the amount of time needed or training required to effectively utilise the strategy. Using a diagnostic that is multi-tiered,
Fisher et al. (2011) have created a reliable method to assess students’ understanding of osmosis (the Osmosis and Diffusion Conceptual Assessment). Students answer multi-choice questions and in addition provide reasoning for their answer. By having to explain their answers students are less likely to answer based on sighting of key words meaning a deeper level of question reading and thinking about the answer (Fisher, et al., 2011; Prosser & Trigwell, 1999).

Scaffolding

Scaffolding as the name suggests is mediating support to students while they learn (Vygotsky, 1978, cited in Novak & Pelaez, 2004). Just like physical scaffolding, help can be removed as students become confident and are able to think for themselves. In addition, scaffolding can help educators determine a student’s zone of proximal development. When a teacher identifies what level of help students need to progress it can lessen the frustration students feel without pushing the students too far out of their comfort zone (Vygotsky, 1978, cited in Novak & Pelaez, 2004). With the help of someone with a greater level of knowledge a learner can successfully do more than if that learner had worked by themselves (De Grave, Dolmans, & Van der Vluten, 1999).

By giving support as learning occurs a deeper level of learning can take place (Chin & Brown, 2000). Deep learning involves the big picture, a move away from merely memorising definitions (Biggs, 2003; Prosser & Trigwell, 1999). With deeper learning students should be able to problem solve better and make links between new and existing knowledge (Biggs, 2003). Shifting students towards a deeper learning approach increases the quality of their learning (Prosser & Trigwell, 1999). They are more likely to make connections than students using a shallow surface approach, this
holistic approach is essential in the sciences where concepts learned can be applied cross-disciplinary.

When scaffolding involves conversational feedback it is also possible to identify where misconceptions may be occurring. When prior knowledge and newly acquired knowledge meet but conflict deep learning cannot occur (Chin & Brown, 2000). Instead students will revert to memorisation of facts and ultimately run in to problems. Scaffolding can therefore help to bridge the gap between prior and new knowledge, but also help to break down incorrect or misunderstood ideas.

*Inquiry-based Learning*

Scaffolding is one strategy to support students in their journey to intellectual independence. Another complementary strategy is inquiry-based learning. Inquiry-based learning is an approach that encourages students to gain knowledge through experience, often in the form of problem solving (Anderson, 2002). This constructivist approach allows for active engagement where students are central to their learning. While research on inquiry learning is mixed, it appears to be weighted towards positive results (see Anderson, 2002 for meta-study conclusions). This style of learning though is ideal in the context of the laboratory. Inquiry learning mimics the standard practices of science (Achiam, Sølberg, & Evans, 2013). When teaching science, it is important to teach more than knowledge; students must be able to formulate and test hypotheses, interpret data and draw conclusions. While traditional cook-book style science allows for some facets of the scientific method to be used, inquiry learning is far more holistic.
For the proposed initiative students will be provided with a basic experiment that is not complete (see appendix 1). Giving them complete free range to design an entire experiment is too much work for a limited (3 hour) session, but having only a partially completed experiment allows them to appreciate some aspects of experimental design. In addition having to generate and test an hypothesis is such a fundamental aspect of science. This is not the first time they have encountered this style of laboratory work, many experiments they perform in the lab involve proposing an hypothesis and selecting treatments from option given. With the osmosis initiative there is the added layer of needing to work with their peers co-operatively to ascertain what the treatments should actually be and how they would set them up.

Co-operative learning

Co-operative learning involves students working together to increase the learning of all members of the group (Johnson & Johnson, 2009). It should be noted that this encompasses more than students merely working together in groups, it extends beyond that to students working together towards a common goal or reward. Social interdependence theory suggests that the behaviour of one person will change when others are relying on them. This will be more prominent in students that have established a co-operative base group, a stable group that should provide an environment in which students are happy to exchange and explore ideas (Johnson & Johnson, 2009).

When these inter-dependencies result in positive results (goal or reward) there is evidence that co-operative learning results in greater understanding (higher achievement) and increased interpersonal skills (Johnson & Johnson, 2009; Johnson, Johnson & Smith, 1991). Student-student interactions allow students to learn more
from the content because they hear how their peers have interpreted the information (Biggs, 2003). This increases not just knowledge gained, but also helps students to think differently as they explore how other people arrive to a given conclusion. Socially, working as a team not only improves communication skills, but builds friendships which are valuable in any setting (Biggs, 2003).

**Study Aims and Hypotheses**

Through teaching an osmosis experiment that allows students to generate and test hypotheses (and therefore their understanding) students will attain a better understanding of osmosis. The use of a pre- and post-diagnostic test will quantitatively show a change in understanding for the current cohort of BIOL102 students, with the expectation that post-intervention scores will be higher. In addition a comparison between the 2013 and 2014 cohorts’ test marks around osmotic questions will reveal if the intervention has played a role in increasing student grades.
Current Practice and Proposed Initiative

Current Experiment

Traditionally the topic of osmosis has never been explicitly taught in the laboratory session, instead students are given an applied situation in which osmosis is occurring in a living animal (Nereis sp.). The Nereis is a marine worm, during the experiment they are exposed to different levels of saline concentrations and weighed to determine if they lose or gain weight (see appendix 2 for full experiment). This experiment focuses on the concepts of osmotic regulation (examining how organisms do or do not maintain constant internal solute concentrations). For this experiment to be well understood students need to not only understand what osmosis is, but what drives osmosis. They are expected to assimilate new language such as hyper-osmotic and be able to correctly apply the term to a given situation.

At present this experiment is not ideal for a multitude of reasons, not limited to the lack of student understanding. Nereis sp. are an invertebrate and not subject to any animal ethical regulations, however the stress of the experiment on the worms often causes them to die. This is an unnecessary death when the experiment itself is not an effective teaching tool. In addition we are restricted by the types of animals that we can use in this experiment, making Nereis sp. our only subject option, after a decade of removing these worms from the environment we are altering the natural population making this an unsustainable experiment.
Proposed Initiative

The initiative is built around changing the *Nereis* experiment to a simple demonstration of osmosis in action (see appendix 1 for full experiment). The initiative will start with a pre-diagnostic survey assessing students’ understanding of osmosis. This is the Osmosis and Diffusion Conceptual Assessment (ODCA), a two tiered multi-choice quiz that asks students to not only identify the correct answer to a given problem, but to give the reason (Fisher, Williams & Lineback, 2011, see appendix 3). The quiz will be anonymous, and repeated after the initiative as a measure of change.

During the experiment itself students will be working with a peer, and then a group of eight to conduct the experiment [co-operative learning]. They will be expected to generate a hypothesis and determine the correct solutes to use [inquiry-based learning]. For example a student peer testing a hyper-osmotic environment will need to recognise the key word of hyper-osmotic, realise it is relevant and then come to the conclusion that they will need an “environment” that is more concentrated than the internal membrane. This gives the students some challenge but they are able to work with others to determine if their interpretation of internal/external relationship is correct, allowing for the validation of their existing knowledge. In addition students will be provided conversational feedback during the set-up and running of the experiment, this works not just as a safety net but can help to identify where students might be getting confused [scaffolding].

The initiative therefore should cater to a wide range of students and abilities, this is important if osmosis is a threshold concept as suggested by Taylor (2010). Not all students will be ready to assimilate the information at the same speed. With this in mind there is a possibility of extending the teaching of osmosis in the B semester where again we address the concept of molecule movement during an experiment on dialysis.
Key competencies the new initiative will address

- Expansion of vocabulary
- Generation and testing of hypothesis
- Communication skills (written and verbal)
- Inter-personal skills
- Concept of osmosis
- Measuring (units and scale)

**Implementation**

*Osmosis and Diffusion Conceptual Assessment*

During the first laboratory classes of BIOL102 (March, 2014), all students were asked to fill out the Osmosis and Diffusion Conceptual Assessment (ODCA). Students were told this was for a piece of research to inform the teacher if a teaching initiative had made an impact, that it was anonymous, optional and not worth any grades. This process was then repeated two weeks post-initiative. The two week latency was due to in class testing of the lab in question. All results were then collated and compared.

*Laboratory Class*

The students are provided with a laboratory manual that has all of their experiments for the semester, therefore the initiative was already incorporated into their laboratory manual and as such students were unaware that it was different from any other laboratory session. Students performed the experiment as instructed, working together with their peers as well as teaching staff. During set-up in particular there
was a lot of conversation generated around osmosis some of which were noted down. During this time observations were also made around how well the experiment worked, how well the students worked together and the general sense of understanding.

Testing

At the start of every laboratory session the students sit a short (10 minute) test assessing their learning from the previous week. Therefore the week following the initiative students were given a test with one question (in actuality it is four questions, because students sit in groups of four, all students have slightly different questions to avoid cheating) on each test specifically giving them a more applied problem than what they simply did in the lab. The use of this question was because in a previous year the same question had been used and knowing that this initiative was planned the results of it individually analysed, therefore the ability to compare pre- and post-initiative test scores was possible.
Results

It is possible to evaluate the initiative by breaking down the results from key three components. A within cohort evaluation showing how students understood osmosis before and after undertaking the experiment (using the ODCA survey) as well as a between cohort analysis comparing test marks from 2013 and 2014 classes. There were also observations made during the experiment that allow for evaluation (and reflection) of the task.

Osmosis and diffusion conceptual assessment

In comparing the ODCA results for the students that received the initiative there was a great deal of variation in understanding around osmosis. The pre-testing showed some questions students clearly understood (for example one question showed 98.9% accuracy) while others showed a poor knowledge (question 4 = 6.8% accuracy) (figure 1). It is not surprising then to see that the overall mean across all questions was 56%. What was noticeable was students did better on the first tier of questions that asked what would happen in a particular situation, while the second tier of questions asking for the reasoning was more poorly answered.
Figure 1. Pre-test (dark grey) and post-test (light grey) accuracy results for the osmosis and diffusion conceptual assessment.

Post-test there was less variation (figure 1). One question was answered correctly by all but one student, and six questions had an accuracy rate within the 90-100% range (compared to three questions pre-test). Question four that originally saw less than 1 in 10 students having the correct answer increased to one third of the class achieving the correct result. The overall accuracy mean post-testing was 75.2%.
Between cohort

Comparing the results from the lab test question between the pre-initiative 2013 class and the initiative 2014 class it is clear that there has been an overall increase in understanding of how to answer a theoretical osmosis problem. Students were asked one of four questions:

1. An osmoconformer with an internal salt concentration of 2.5% is placed into a solution of salt water that is 16.5% salt. The animal will:
   
   Gain water / lose water / stay relatively the same

The four questions varied by changing the percentage values for solution and/or organism but otherwise the questions were the same. Approximately half of the students in 2013 got this question right (53.6%) compared to nearly three quarters of 2014 students obtaining the correct answer (72.3%). While there was an element of chance (students who did not know the answer may have been able to correctly guess), there was a clear shift towards the correct answer.

Observations and conversations during the initiative

Prior to the practical session the lectures on osmoregulation had concluded meaning students had received theoretical explanations around osmosis and some of the key terminology to be used. In addition some students had also had tutorial classes around osmosis where it was stressed that osmosis can be confusing and the importance of seeking help and clarification as needed. During the laboratory students were encouraged
to discuss their hypothesis with one another, as well as teaching staff involved. This gave opportunity to question students’ understanding and reasoning.

It quickly became apparent that while students could define osmosis many students found it difficult to predict which way water would move in their experimental set up. Even more apparent was how many students struggled with the use of correct terminology of hyper-, hypo- and isomotic. This is turn lead to confusion even with the teaching staff because students were unable to clearly ask questions because they were often mixing up these terms and missing the importance of relativity. For example:

Student 1: Is this correct [points to their set-up]?

Teacher 1: That depends, what are you testing? Can you describe what your set up is?
Student 1: Hypo-osmotic [pause]. We have a hypo-osmotic set up, that is what we are testing.

Teacher 1: Remember it is relative, can you describe your set up, where is the highest concentration?

Student 1: Um, I have saline in the beaker, so that is more concentrated.

Teacher 1: Ok, so now tell me what hypo-osmotic means?

Student 1: It means [pause] that there is more, no less salt or whatever, less solute concentration. Oh right, so less concentration is in the tube, right?

Teacher 1: Cool, so now remember its relative. You can’t just say your set-up is hypo-osmotic because you need to tell me what part is less concentrated. In this case, you have a hyper-osmotic environment, the greater concentration is on the outside. Does that make sense?

Student 1: Um, so then that means if this was an animal that the animal is hypo-osmotic to the environment?

Teacher 1: Bingo, just remember you need to have that comparison, that relativity in there.
Once students had set the experiment up and could see the different solutions (the concentrated solution was blue so visibly different), but before the experiment had a chance to work, some students were then able to make a correct prediction. It seemed the act of setting up the experiment had given them a bit more time to think about how it would work. There were more than a few “I get it now” comments, and students were able to look at their experimental treatment and make predictions of what would happen in the other treatments even if they could not see those treatments.

Overall from conversations it appeared that students had a better understanding of osmosis after completing the experiment, but still struggled with the terminology.

Discussion and reflection

The aim of this initiative was to raise the understanding of osmosis for a first year biology class. It is clear that there was a positive shift in understanding, with students scoring better on average for the ODCA after the initiative when compared to pre-initiative. In addition comparing student test scores between years there was evidence for greater understanding for students who participated in the initiative with an almost 20% increase in students answering a hypothetical osmosis problem correctly. With this evidence and through conversations with students it is possible to say that the initiative was a success.

On reflection there are a number of things I have identified that I will try in the next iteration of the paper. One area that students still clearly struggled with was key terminology. There is potential to introduce students to these terms earlier in the semester (when students learn about the transport of nutrients in plants). This would increase familiarity around the problematic language (e.g. hyperosmotic etc.). I would also discuss
the terms more during the laboratory and add them in to my learning objectives for that session (and subsequently have them in a test question to follow up and assess their understanding). I would also spend more time with my demonstrators to ensure they had a very good understanding themselves of the terminology as it became apparent that even graduate students were getting confused (partly due to perhaps their own knowledge level and party due to the way the first year students were phrasing their questions).

Language acquisition within biology makes up such a large component of first year and it is important that students have a good understanding of what the words they use mean. Merely being able to parrot a definition shows the shallow level of learning, but when students start to develop a sense of the roots of biology language (predominantly Latin bases) they start seeing connections between words and show evidence of moving towards deeper learning. I tried to utilise this when teaching hyper- hypo- and isosmotic by using terms students would be familiar with. For example I asked students to explain what being hyperactive would look like (lots of energy, therefore hyper is high or above) and what hypothermic meant (emphasising hypo means low). However I only did this with my tutorial students (around 15% of the cohort experiencing the initiative), in hindsight I would use this method of teaching more generally, starting with teaching it this way to my demonstrators so that they could also use model. I firmly believe that if students can have a better grasp of the key terminology it will help them in explaining the phenomenon of osmosis, and in turn move them from the liminal state they find themselves in and transform their learning (Meyer & Land, 2005).

When considering the background of first year students, the knowledge they enter university with varies substantially. We have a general expectation of what our students know, although research has shown that often students have not gained a full
understanding and instead their learning is far more disjointed, lacking in some key areas (Ross, et al., 2010). Looking at the composition of the class there was a significant number of mature students (greater than 25 years old), international students, or students who did not complete Biology at NCEA Level 3. While teaching the osmosis initiative it became apparent that some students had a clear understanding, probing these students they had done a similar experiment at school. However the majority of students had not had any experimental challenges around osmosis at school. I had feared that the experiment would be too basic but feel confident now that this is not the case.

Moving away from the topic of osmosis, I can see potential in creating diagnostic surveys similar to the ODCA. A number of key concepts have been identified in the literature as the problematic areas for biology such as photosynthesis, cellular metabolism (both of which interestingly requires an understanding of osmosis and concentration gradients), natural selection, and scale (Griffiths & Preston, 1992; Ross, et al., 2010; Taylor, 2010). Of these potential threshold concepts only photosynthesis (to my knowledge) has a two-tiered diagnostic assessment (Griffard & Wandersee, 2001). I would like therefore to try and create a similar tool around natural selection and cellular metabolism. Both of these topics are taught in the B-semester biology paper, and both cause students to struggle. Natural selection students will report that they understand but in actuality their comprehension is at a very basic level and they are unable to integrate what they learn in genetics to their understanding of natural selection. Cellular metabolism is the one topic identified again and again as the hardest topic in first year biology (not just difficult to learn, but it is also difficult to teach). Therefore any tool that can be developed that might help identify misconceptions and mistakes would benefit the student and the teacher alike.
Summary

This research supports the current literature that has identified osmosis as a problematic concept within biology, but furthermore I have supplied evidence to show that through simple changes it is possible to increase the overall understanding. Using a variety of teaching techniques including scaffolding, inquiry-based learning and co-operative learning students in a first year biology class were able to successfully demonstrate their ability to generate (and subsequently test) a hypothesis around osmosis and showed evidence of greater understanding.

Furthermore the pilot initiative showed an unanticipated gap in students’ understanding in relation to key terminology. This will be addressed in future initiatives. The helpfulness of the diagnostic tool has led to the idea that these tools could be designed to assist students; learning of other troublesome knowledge.
References


Appendix

1. New experiment, simplified osmosis experiment

<table>
<thead>
<tr>
<th>Materials</th>
<th>Per Pair</th>
<th>Per Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialysis tubing</td>
<td>10 mL glass Pipette</td>
<td>Saline solution dyed blue (5M NaCl)</td>
</tr>
<tr>
<td>Flask</td>
<td>Rubber bands x2</td>
<td>Distilled water</td>
</tr>
</tbody>
</table>

Procedure

1. Each full bench (8 students) will set up four conditions. Discuss with your bench mates which pair will test which treatment from the list below, once your pair has their assigned treatment generate an hypothesis on what you think will happen in your treatment. Discuss your hypothesis with other group members and/or demonstrator.

2. The four conditions to be tested are:
   - Hyperosmotic environment
   - Hypoosmotic environment
   - Isosmotic environment (saline)
   - Isosmotic environment (fresh water)

3. The experimental set up can be seen in figure 8.1. Wet your dialysis tube before sealing it on to the glass pipette using a rubber band (approximately 1cm from the top of the tube). Seal the bottom of the tubing with the second rubber band.

4. Insert the pipette and tube into a flask before clamping to the retort stand.

5. In a small beaker collect some distilled water and/or saline, as appropriate to your set up

6. Using the plastic transfer pipette fill the pipette with either distilled or saline water. Your dialysis tubing should fill up but a small pocket of air will remain. Continue to fill until the pipette itself is half full.

7. Add either saline or distilled water to the flask, pouring carefully to avoid spillage. If any saline is spilled please clean immediately. The flask should be almost completely full.

8. Note the volume in the pipette and record this as 0min (table 8.1).

9. Check your pipette volume every 5min for 20min and fill in table 8.1.

Figure 8.1. Osmosis demonstration apparatus set up (Image: B. Tulloch)
### Results

Table 8.1. 
**Pipette volume measurements taken every 5min**

<table>
<thead>
<tr>
<th></th>
<th>0min</th>
<th>5min</th>
<th>10min</th>
<th>15min</th>
<th>20min</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hypoosmotic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hyperosmotic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Isosmotic (saline)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Isomostic (fresh)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Evaluation

- What happened *in terms of water movement* in each environment? Is this what was expected?
  
  Hypoosmotic:
  
  Hyperosmotic:
  
  Isosmotic (saline):
  
  Isosmotic (fresh):

- Which environment had the greatest change of volume? Based on your hypothesis is this what you expected?

- If an organism that is categorised as an *osmoregulator* (check your pre-lab if you've forgotten this term) that normally lives in salt water was placed in to a beaker of distilled water what do you think might happen? What about if the animal was an *osmoconformer*?

- What type of *environments* would contain marine organisms that are likely to be very good osmoregulators?
2. Old *Nereis* experiment

**Materials**
Per group of four students
*Nereis* in crystallising dish

**Procedure**
1. Very gently blot excess water off a *Nereis* worm and weigh on plastic tray.
2. Place the worm in one of the following assigned solutions: distilled water, 20%, 40%, 60%, 80% or 100% seawater.
3. Re-weigh the worm every 10 minutes for 30 minutes. **Use the same balance throughout.** Zero the balance carefully before each weighing and take care blotting your worm dry.
4. Return to 100% seawater at the end of 30 minutes and re-weigh every 10 minutes for a further 30 minutes.

**Results**
1. Record your own results on Table 2.1 below and class averages in to table 2.2.

<table>
<thead>
<tr>
<th>Table 2.1: Weight changes in <em>Nereis</em> over 90 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Salinity</strong></td>
</tr>
<tr>
<td>% sea water =</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>100% sea water</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2.2: Class Results: % of Initial Weight over time, for each salinity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time</strong></td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>30/0</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>30</td>
</tr>
</tbody>
</table>
2. Plot the class results on the graph paper provided.

**Evaluation**

- For which initial salinities was *Nereis* unable to regain approximately its initial weight when it was later placed in 100% seawater? I.e. look at the class results, which salinities were furthest away from 100%

- Is *Nereis* an osmoregulator or an osmoconformer? Why do you think this?

- What type of environments would contain marine organisms that are likely to be very good osmoregulators?
3. Osmosis and Diffusion Conceptual Assessment (ODCA)

This short quiz is to help me identify the classes’ knowledge of osmosis. There is no grade recorded as it is anonymous.

1. All cell membranes are
   a. semipermeable
   b. permeable
2. The reason for my answer is because cell membranes
   a. allow free movement of materials into or out of the cell.
   b. allow some substances to enter the cell, while they prevent all substances from leaving.
   c. allow only beneficial materials to enter the cell.
   d. allow some substances to pass through, but not others.

3. During the process of diffusion, particles will generally move from
   a. high to low concentration
   b. low to high concentration
4. The reason for my answer is because
   a. crowded particles want to move to an area with more room.
   b. the random motion of particles suspended in a fluid results in their uniform distribution.
   c. the particles tend to keep moving until they are uniformly distributed and then they stop moving.
   d. there is a greater chance of the particles repelling each other.

5. If a small amount of salt (5g) is added to a large container of water (4L) and allowed to set for several days without stirring, the salt molecules will
   a. be more concentrated on the bottom of the water.
   b. be evenly distributed throughout the container.
6. The reason for my answer is because
   a. salt is heavier than water and will sink.
   b. salt dissolves poorly or not at all in water.
   c. there will be more time for settling.
   d. there is movement of particles from a high to low concentration.

7. Two columns of water are separated by a semipermeable membrane through which only water molecules can pass. Side 1 contains brown dye and water; Side 2 contains pure water. After two hours, the water level in Side 1 will be...
   a. higher than in Side 2.
   b. lower than in Side 2.
   c. the same height as in side 2.
8. The reason for my answer is because
   a. water will move from high to low solute concentration.
   b. water flows freely and maintains equal levels on both sides.
   c. the concentration of water molecules is less on Side 1.
   d. water moves from low to high water concentration.
9. Suppose there are two large beakers with equal amounts of clear water at two different temperatures. Next, a drop of green dye is added to each beaker of water. Eventually the water turns light green. In which beaker does the water become evenly coloured light green first?
   a. Beaker 1 (20°C)
   b. Beaker 2 (25°C)

10. The reason for my answer is because
   a. the dye breaks down more quickly.
   b. moving slower makes it easier for the molecules to move.
   c. the dye molecules move faster.
   d. temperature changes the size of the molecules.

11. A water-based solution is placed on the left side of a container that is divided by a semipermeable membrane. Pure water is on the right. As time passes, the right side gradually becomes blue, while the blue colour on the left side becomes lighter. This suggests that
   a. the level of the liquids on both sides will remain the same.
   b. the level of the liquid will decrease on Side 1 and increase on Side 2.
   c. the level of the liquid will increase on Side 1 and decrease on Side 2.

12. The reason for my answers is that
   a. water and dye can both pass through the membrane.
   b. the dye can pass through the membrane but moves more slowly than water.
   c. the dye moves into Side 2 and raises the level of the liquid.
   d. atmospheric pressure will always produce equal water levels.

13. When a living human blood cell is placed in pure fresh water, the cell will
   a. shrivel up.
   b. swell and burst.
   c. remain the same.

14. The reason for my answer is because
   a. water molecules move from higher concentration of dissolved particles to lower concentration of dissolved particles.
   b. a cell has homeostasis and will maintain itself.
   c. the cell loses stability outside the human body.
   d. water molecules move from higher concentration of water to lower concentration of water.

15. Suppose you add a drop of blue dye to a container of clear water and after several hours the fluid is evenly colored light blue. At this time, the molecules of dye
   a. have stopped moving.
   b. continue to move around randomly.

16. The reason for my answer is because
   a. molecules move until they are evenly distributed, and then they stop.
   b. if the dye molecules stopped, they would settle to the bottom of the container.
   c. when molecules are evenly distributed, they still continue to move.
   d. this is a liquid system. If it were a solid the molecules would stop moving.
17. The figure below depicts a case where two water solutions have just been introduced into two identical beakers. The volume of the solution in each beaker is the same. At this point, Beaker 1 contains
   a. more water than Beaker 2.
   b. less water than Beaker 2.
   c. the same amount of water as Beaker 2.
18. The reason for my answer is because
   a. the liquids are the same heights in both beakers
   b. water in Beaker 1 contains more dissolved particles.
   c. water in Beaker 1 contains fewer dissolved particles