**Please do not write on paper**

**The Properties of Water**

Water is everywhere. It's in the air we breathe. It's in our sink faucets, and it's in every cell of our body. Water is an unusual substance with special properties. Just think about the wonder of water:

1. How does water rise from the roots of a redwood tree to the very top?
2. How do insects walk on water?
3. Why does ice float rather than sink?
4. Why do people become seriously ill, or die, if they go without [**liquid**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#liquid) for a week or so?
5. How would life in a lake be affected if ice sank and lakes froze from the bottom up?

In this first lab, we will investigate the properties of water in an attempt to understand how water behaves in relation to both our bodies and the environment. Through a concise set of experiments, the unique properties of water and its consequent importance to living things will become apparent.

Supplies

10ml graduated cylinders Wax paper Pennies food coloring Detergent

50 ml graduated cylinders cooking oil Water stirring rods Glass slides

Medicine droppers

Once you have completed this exercise you should be able to:

1. Describe the [**polarity**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#polarity) of a water molecule and explain how that [**polarity**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#polarity) affects the properties of water.
2. Explain why oil and water don't mix.
3. Predict whether a substance, based on its [**hydrophilic**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#hydrophilic) and/or [**hydrophobic**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#hydrophobic) properties, will dissolve into water or oil.

**Background Information**

Water covers about three fourths of the surface of the earth? It is ubiquitous. It is also one of the simplest yet most important molecules in living systems. It makes up from 50 to 95 percent of the weight of living organisms. The cytoplasm of a cell is a water-based solution that contains a variety of ions, salts, and molecules which make life 'happen.' Water is literally involved in every facet of life.

**Figure 2. Polarity of Water Molecule**



The simplicity of the water molecule belies the complexity of its properties. Based on its small size and light weight, one can predict how it *should* behave, yet it remains [**liquid**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#liquid) at a much higher temperatures than expected. It also [**boils**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#boil) and [**freezes**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#freeze) at much too high, or low, of a temperature for a molecule of its size. Many of these unexpected properties of water are due to the fact that water molecules are attracted to each other like small magnets ([**cohesion**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#cohesion)). This attraction results in turn from the structure of the water molecule and the characteristics of the atoms it contains.

Each molecule of water is made up of two atoms of hydrogen connected to one atom of oxygen, as shown below. This is summarized in the familiar formula, H2O.

**Figure 3. Hydrogen Bonding in Water**



**Powerful Idea**

Atoms are most stable when they have a particular configuration of their outer shells, a concept which will be discussed in future labs. These configurations explain why hydrogen in water will take on a **partial positive charge** and why oxygen will take on a **partial negative charge**. These partial charges cause water molecules to 'stick' to each other like magnets. *The 'stickiness' in this particular case is due to '*[***hydrogen bonding***](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#hydrogen)*'. In this case, hydrogen bonding involves the attraction between the positively charged hydrogen atom of one water molecule and the negatively charged oxygen atom of another water molecule.* As no electrons are actually shared however, **hydrogen bonds** are much weaker than covalent bonds - they easily break and easily form again.

**Surface Tension & Adhesion**

**Exercise 1**

**1a Drop Behavior - Water on Penny**

1. Obtain a medicine dropper and a small (10 ml) graduated cylinder. Make sure the dropper is clean.
2. Drop water into the graduated cylinder with the dropper, counting each drop.
3. How many drops, of the size produced by your medicine dropper, are in each cubic centimeter (cc) of water? (1 cubic centimeter = 1 milliliter)? \_\_\_\_\_\_\_\_\_\_ drops
4. Conversely, how much water is in each drop? (divide 1cc by the number of drops) \_\_\_\_\_\_\_\_\_\_ cc. per drop, average.
5. Now, let's see how many drops of water you can you place on the surface of a penny before it overflows.
6. How many drops do you predict?

**Table 1. Number of Drops Predicted**

|  |  |  |
| --- | --- | --- |
| Person | #1 |   |
| Person | #2 |   |
| Person | #3 |   |
| Person | #4 |   |
| Total | 1 – 4 |   |
| Average |   |   |

1. Drop water from the dropper onto a penny, keeping careful count of each drop. Draw a diagram below showing the shape of the water on the penny after one drop, when the penny is about half full, and just before it overflows.

**Figure 4. Drawing of Drops**



1. How many drops were you able to place on the surface of the penny before it overflowed? \_\_\_\_\_\_\_\_\_\_ drops
2. If the number of drops is very different from your prediction, explain what accounts for the difference. Explain your results in terms of [**cohesion**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#cohesion)

**1b Effects of Detergent**

1. With your finger, spread one small drop of [**detergent**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#detergent) on the surface of a dry penny.
2. How many drops do you think this penny will hold after being smeared with [**detergent**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#detergent), more, less, or the same as before? Why?
3. Specifically, how many drops do you think it will hold?

**Table 2. Prediction of Number of Drops of Water on a Penny with Detergent**

|  |  |  |
| --- | --- | --- |
| Person | #1 |   |
| Person | #2 |   |
| Person | #3 |   |
| Person | #4 |   |
| Average |   |   |

1. Using the same dropper as before, add drops of water to the penny surface. Keep careful count of the number of drops, and draw the water on the penny after one drop, about half full, and just before overflowing.

**Figure 5. Drawing of Drops on a Penny with Detergent**



1. How many drops were you able to place on the penny before it overflowed this time? \_\_\_\_\_\_\_\_\_\_ drops
2. Did the [**detergent**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#detergent) make a difference? Describe the effect of the [**detergent**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#detergent).
3. What does the [**detergent**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#detergent) do to have this effect on water? Explain how [**detergents**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#detergent) act as cleaning agents, considering the [**cohesion**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#cohesion) among water molecules and the affects of **amphipathic molecules** (of a molecule having two different affinities, as a polar end that is attracted to water and a nonpolar end that is repelled by it).

**1c Drop Shape on Glass and Wax Paper**

1. What will be the shape of a drop of water on (a) a piece of wax paper and (b) a glass slide? Draw the shape of the drop you expect on each surface:

 \_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_

 wax paper glass slide

1. Why did you predict as you did? What assumptions are guiding your thinking?
2. Perform the experiment. Place several drops of water on each surface and draw the results below.

 \_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_

 wax paper glass

1. Compare your predictions with your observations and explain.
2. Can you explain the differences in drop behavior in terms of [**adhesion**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#adhesion) - that is, the formation (or absence) of [**hydrogen bonds**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#hydrogen) between molecules of different types? Which molecules?

**Exercise 2**

**Cohesion of Water**

**2a Water & Oil**

1. Put 8 ml of water into a 10 ml graduated cylinder.
2. What will happen if you add cooking oil? (Predict by choosing a, b, c, d, or e below)
a. the oil will float on top of the water
b. the oil will sink to the bottom of the water
c. the oil will dissolve in the water
d. the oil will become mixed up with the water
e. other (what?)

Oil is a [**hydrophobic**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#hydrophobic) or 'water hating' molecule, so called because its chemical structure does not allow the formation of hydrogen bonds. Therefore, oil does not dissolve in water. When mixed, the two substances form separate layers, and because oil is less dense, it sits on top of water.

**Figure 9. Water and Oil**



1. Gently add 2 ml of cooking oil by tilting the cylinder of water slightly and letting the oil run slowly down the inside of the cylinder.
2. What happened?
3. Save this graduated cylinder with its contents and get a clean 10 ml cylinder for the next experiment.

**2b Oil & Water**

1. Place 8 ml of cooking oil in a 10 ml graduated cylinder.
2. What will happen when you add water? (Predict by choosing a, b, c, d, or e below)
a. the water will float on top of the oil
b. the water will sink to the bottom of the oil
c. the water will dissolve in the oil
d. the water will become mixed up with the oil
e. other (what?)
3. Gently add 2 ml of water by tilting the cylinder of oil slightly and letting the water run slowly down the inside of the cylinder. What happened?
4. Which is less dense (that is that has less weight per ml.), oil or water? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. Explain how this characteristic behavior of water and oil is of critical importance for living thing. Consider the picture that follows:

**Figure 10. Enlargement of Cell Membrane to Show Phospholipid Bilayer.**



1. What mechanism causes water molecules and oil molecules to separate from one another? Your explanation should involve [**polar**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#polar) and [**non-polar**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#nonpolar) molecules, the effects of [**polarity**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#polarity) on the molecular interactions, and [**hydrogen bonding**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#hydrogen).

**2c Water, Oil, and Dye**

1. Predict what will happen if you add a few drops of a water-soluble dye solution to each of the above graduated cylinders containing water and oil. Will the dye mix with the water, the oil, or both?
2. Perform the experiment. Add a few drops of dye to each cylinder. Use a glass stirring rod to penetrate the interface between each layer, giving the dye access to both water and oil.
3. How does the dye behave in each cylinder? Does it diffuse into the oil? Into the water?
4. Compare your predictions and results. Explain any differences.
5. Stir the contents of each cylinder with a stirring rod and then let it sit.
6. Will the contents remain mixed? Why do you think so?
7. Observe what happens, compare with your prediction, and explain why it happens. Your explanation should involve [**polarity**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#polarity), [**polar**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#polar) and [**non-polar**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#nonpolar) molecules, **solution** and [**hydrogen bonding**](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#hydrogen).

**Exercise 2**

**Class Summary**

1. Summarize class results with respect to drops on a penny in the table below.

**Table 4. Number of Drops on a Penny**

|  |  |  |
| --- | --- | --- |
| **Group** | **# Drops without Detergent** | **# Drops with Detergent** |
| **1** |   |   |
| **2** |   |   |
| **3** |   |   |
| **4** |   |   |
| **5** |   |   |
| **6** |   |   |
| **7** |   |   |
| **8** |   |   |
| **Average** |   |   |

1. Explain the variation from group to group
2. What general conclusions can you draw from the class data?
3. Explain the how the ideas you learned in this relate to each other.

**Organizing Your Knowledge**

1. Describe at least one observation you have made outside the laboratory that illustrates each phenomenon below.
	1. [Polarity](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#polarity)
	2. [Hydrogen bonds](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#hydrogen)
	3. [Cohesion](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#cohesion)
	4. [Surface tension](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#surface)
	5. [Amphipathic](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#amphipathic)
	6. Dissolving
	7. [Density](http://www.biologylessons.sdsu.edu/ta/classes/lab1/glossary.html#density)