Name _____

Properties of Water Lab

For more help with the concepts in this lab, visit www.bozemanscience.com/ap-biology/ and watch the **AP Biology Water: A Polar Molecule** video. Also visit www.bozemanscience.com/statistics-graphing/ and watch the **Standard Deviation and Standard Error** videos.

Content Standards:

- **EU 2. A. 3**: Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.
- **SP2**: The student can use mathematics appropriately.
- **SP5**: The student can perform data analysis and evaluation of evidence.
- **SP6**: The student can work with scientific explanations and theories.

Background Information:

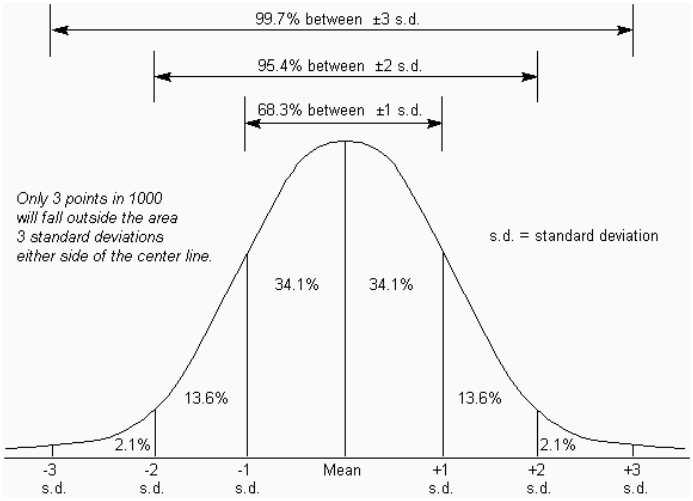
Water is a ***polar*** molecule. The oxygen atom in water has a greater ***electronegativity***, or a stronger "pull," on the electrons that it shares with the two hydrogens it is covalently bonded to. As a result, the molecule ends up having a **partially negatively charged end**, near the **oxygen**, and a **partially positively charged end** near the **hydrogens**. Much like a magnet, opposite charges will attract and similar ones will repel so that the slightly negatively charged oxygen of one water molecule will be attracted to the slightly positively charged hydrogen of a neighboring water molecule. This weak attraction and "sticking together" of polar molecules is called ***hydrogen bonding***.

Water is an extremely important molecule in biology. Life came from the earliest watery environments, and thus all life depends upon the unique features of water which result from its polar nature and 'stickiness.' Some of the unique properties of water that allow life to exist are:

- It is less dense as a solid than as a liquid.
- It sticks to itself –***cohesion***– cohesion is also related to surface tension.
- It sticks to other polar or charged molecules –***adhesion***– adhesion results in phenomena such as capillary action.
- It is a great ***solvent*** for other polar or charged molecules.
- It has a very ***high specific heat*** –that is, it can absorb a great deal of heat energy while displaying only small increases in temperature.
- It has a neutral pH of 7, which means the concentrations of H^+ and OH^- ions are equal.

Introduction to Statistics:

Statistical analysis is used to collect a sample size of data which can infer what is occurring in the general population**.** ***Standard deviation*** (often reported as +/-) shows how much variation there is from the average (mean). **If data points are *close* together, the standard deviation with be *small*. If data points are *spread out*, the standard deviation will be *larger.*** Typical data will show a ***normal distribution*** (bell-shaped curve). In normal distribution, about 68% of values are within one standard deviation of the mean, 95% of values are within two standard deviations of the mean, and 99% of the values are within three standard deviations of the mean. The formula for standard deviation is shown to the below, where $\bar{x}$ is the mean, x_i is any given data value, and n is the sample size. Consider the follwing sample problem.



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Standard Deviation

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

Grades on the most recent AP Biology quiz were as follows: 96, 96, 93, 90, 88, 86, 86, 84, 80, 70.

Step 1: Find the **Mean ($\bar{x}$)**. _____

Step 2: Determine the **Deviation ($x_i - \bar{x}$)^2** from the mean for each value and square it, then add up all of the total values. _____

Step 3: Calculate the **Degrees of Freedom (n-1)**. _____

Step 4: Put it all together to find **s**. _____

In the problem above, the mean is 87 and the standard deviation is 8. So one standard deviation would be (87-8) through (87+8), or 79-95 (68% of the data should fall between these numbers). Two standard deviations would be (87-16) through (86+16), or 71-103 (95% of the data should fall between these numbers). Three standard deviations would be (87-24) through (87+24), or 63-111 (99% of the data should fall between these numbers.

Standard error of the mean is used to represent uncertainty in an estimation of mean and accounts for both sample size and variability. The formula used to calculate standard error of the mean is shown below. **As standard error grows smaller, the likelihood that the sample mean is an accurate estimation of the population increases.**

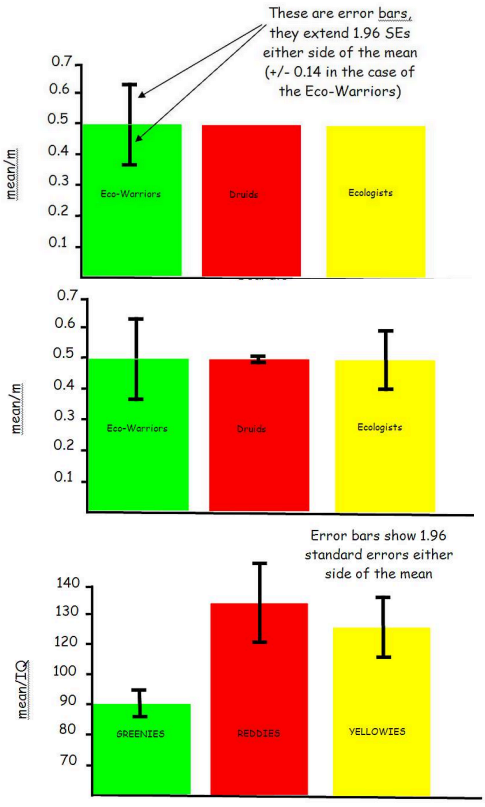
Standard Error

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}}$$

Using the data from the standard deviation example above, the mean is 87 and the standard deviation is 8. Plug in the numbers (remember that ***n*** is 10), and the standard error of the mean equals 2.5 This means that measurements vary by +/- 2.5 from the mean.

It is common practice to add standard error bars to graphs, marking one or two standard error(s) above and below the sample mean (see figure to the right). Such bars give an impression of the ***precision*** of estimation of the mean in each sample. Typically, the length of the bars above and below the mean and the overlap of the bars as compared to one another is analyzed (see figures to the right). The ***length*** of the bars shows the spread around the mean. **Shorter bars indicate less variability from the mean**. If two or more error bars are the *same* size, they have *similar* spreads around their means. If a bar is longer than others, it has a larger spread around its mean.

When the ***range*** of bars ***overlaps***, this indicates that there is ***NOT*** a significant difference in averages and data sets. If the range of bars does not overlap, there *may* be a significant difference in averages and data sets (a t-test must be done to further the investigation). Notice that in the last image, the error bars tell us that we can be 95% confident (2 SEM) that the Greenies mean IQ is significantly different from either the Reddies or the Yellowies. Things are not nearly so clear-cut between the Reddies and the Yellowies. Notice how the error bars of the Reddies and Yellowies overlap, but there is clearly no overlap between both of them and the Greenies.



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Pre-Lab Questions: Use the above background information and your textbook to answer the following questions.

- Why is water considered to be polar?

- Sketch a molecule of water (include the partial charges).

- Which type of bonds form between the oxygen and hydrogen atoms of ***TWO DIFFERENT*** water molecules?

- Which type of bonds form between the oxygen and hydrogen atoms of ***WITHIN*** *a* water molecule?

Purpose:

To examine the effects of different solutes on the adhesive and cohesive properties of water. To analyze your data with statistical methods.

Experimental Design:

Review the materials and methods and complete an EGO on a separate piece of paper prior to beginning your lab.

Materials:

Penny, distilled water, rubbing alcohol, 1M salt water, soap, paper towels, dropper, paper towels, small beakers or cups

Methods:

Methods are given in a two-column format. On the left are the steps you need to follow. On the right you will find questions to answer as well as extra space to record your observations and any changes to the procedure you make.

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Methods	Purposes / Observations / Changes to procedure:
1. Safety: wear goggles while completing this lab.	
2. Obtain a dry penny. Using the dropper, drop distilled water onto a penny, keeping careful count of each drop.	What is the possible impact of tap water? How is tap water different from distilled water?
3. Record how many drops you were able to place on the surface of the penny before it overflowed in Data Table 1.	
4. Dry your penny and repeat the procedure for a total of 5 trials.	
5. Obtain a dropper bottle with liquid soap in it. Using your finger, spread a small drop of soap on the surface of a dry penny.	Predict the number of drops of water the penny will hold when soap has been spread on it. Justify your prediction based on the properties of water.
6. Repeat steps 1-3 with the same penny and dropper. Be sure to reapply a new drop of soap between trials.	
7. Obtain a cup of rubbing alcohol. Rinse your dropper with rubbing alcohol by drawing up sufficient alcohol to fill the stem and then squirting it in the sink. Do this twice.	Why is rinsing the dropper important? Why is rinsing more appropriate than getting a different dropper?
8. Repeat steps 1-3 with the same penny and dropper but with rubbing alcohol. Do not use soap!	Predict the number of drops of rubbing alcohol the penny will hold. Justify your prediction based on the properties of water.
9. Obtain a cup of 1M salt water. Rinse your dropper with salt water by drawing up sufficient alcohol to fill the stem and squirting it in the sink. Do this twice.	

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10. Repeat steps 1-3 with the same penny and dropper but with 1M salt water. Again, no soap!	Predict the number of drops of 1M salt water the penny will hold. Justify your prediction based on the properties of water.
11. Clean-up: return pennies, droppers, soap, and beakers of solutions to the front table. Wipe down your work surface with a wet paper towel.	

Results:

Table 1: Number of drops of a fluid that can be contained on the surface of a penny.

Trial	# drops of Distilled Water on dry penny	# of drops of Distilled Water on penny with soap	# of drops of Rubbing Alcohol on dry penny	# drops of Salt Water on dry penny
1				
2				
3				
4				
5				

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Analysis:

Table 2: Data Analysis of the number of drops of a fluid that can be contained on the surface of a penny.

Calculation	# drops of Distilled Water on dry penny	# of drops of Distilled Water on penny with soap	# of drops of Rubbing Alcohol on dry penny	# drops of Salt Water on dry penny
Mean				
Standard Deviation				
Standard Error				
2SEM				
Mean+2SEM				
Mean-2SEM				

Sample Calculations: Show your work for each of the values in the "# of drops of Distilled Water on dry penny" column. Write the formula used, fill in the appropriate values, and the final answer. You only need to show your work for the first column. After that, just fill your answers in the table.