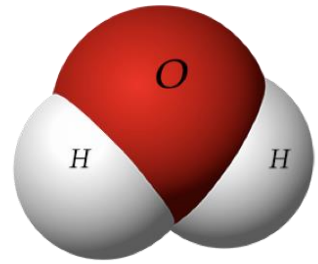
Investigation: Properties of Water with Statistics

AP Biology

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:

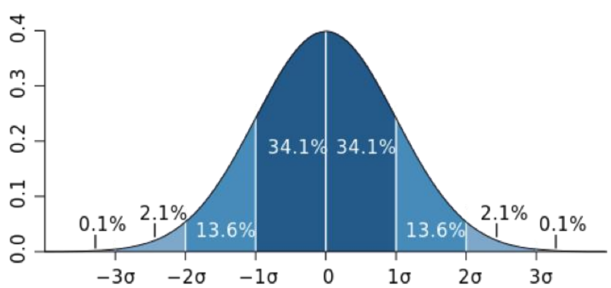
- It is less dense as a solid than as a liquid.
- It sticks to itself –***cohesion***– cohesion is also related to surface tension.
- It sticks to other polar or charged molecules –***adhesion***– adhesion results in phenomena such as capillary action.
- It is a great ***solvent*** for other polar or charged molecules.
- It has a very ***high specific heat*** – 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 **$\bar{x}$**.

The formula for standard deviation is shown to the below, where is the mean, x_i is any given data value, and *n* is the sample size. Consider the following sample problem.



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

Quickcheck: On a normal distribution curve, what percentage of data points will be within 1 standard deviation of the mean? Why does the graph show 34.1%?

Practice Problem: Grades on the most recent AP Biology quiz were: 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 & square it, then add up the total values.
- **Step 3**: Calculate the **Degrees of Freedom (n-1)**.
- **Step 4**: Put it all together to find **s**.
- **Step 5**: Determine the data range for **two standard deviations**:

Answer: 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.

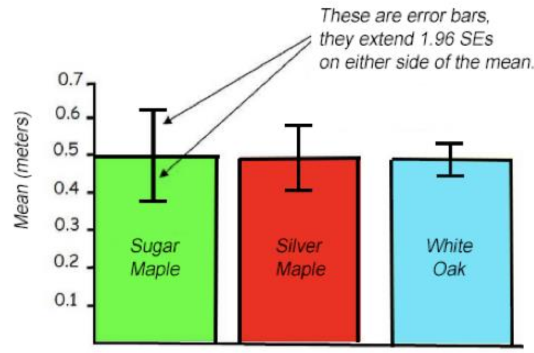
Standard error of the mean is used to represent uncertainty in an estimation of mean and accounts for both sample size and variability. The formula used to calculate the standard error of the mean is shown below. **As standard error grows smaller, the likelihood that the sample mean is an accurate estimation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

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

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.

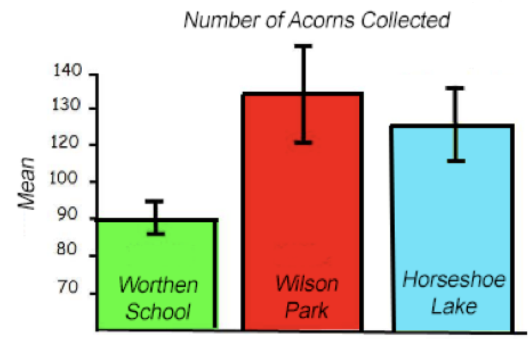
Adapted from www.biologycorner.com

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 the figure 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. In the graph shown, the white oak data shows the least amount of variation around its mean.



When the ***range*** of bars ***overlap***, this indicates that there is ***NOT*** a statistically 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.

Notice that in the last image, the error bars tell us that we can be 95% confident (2 SEM) that the number of acorns collected at Worthen School is significantly different from the Wilson Park and Horseshoe Lake sites. Things are not as clear-cut between Wilson Park and Horseshoe Lake because the error bars overlap.



Research Question: How soap affects hydrogen bonds between different water molecules?

Materials: Penny, distilled water, soap, pipette, paper towel

Procedure:

1. Obtain a DRY penny and place it on a DRY paper towel.
2. Using a clean pipette, add distilled water to the penny drop by drop until it overflows. **<u>Be sure to count the drops!</u>** Record the number of drops for Trial 1 in Data Table 1 below.

3. Repeat steps 1-2 for a total of five trials.
4. Spread a thin layer of Dawn soap over the surface of the penny and then repeat steps to measure the number of drops. Rinse, dry, and add another layer of soap between trials

Data Collection:

Data Table 1: Number of Drops of Distilled Water Contained on the Surface of a Penny

Data Table 2: Statistical Analysis of the Number of Drops of Distilled Water Contained on the Surface of a Penny

Trial	# Drops Distilled Water	# Drops Distilled Water + Soap
1		
2		
3		
4		
5		
Average		

Calculation	# Drops Distilled Water	# Drops Distilled Water + Soap
Mean		
Standard Deviation		
+/- 1 std dev		
+/- 2 std dev		
Standard Error		
+/- 2 SEM		

Deliverable:

- Your final product for this investigation will be turned in via Canvas. Create a QR code and place it in your **BILL**.
- Make sure to include the following sections
  - **Research Question:** How soap affects hydrogen bonds between different water molecules?
  - **Evidence:**
    - *Include the two data tables*
  - **Data Processing:**
    - *An appropriately labeled Bar Graph for the sample means* for the penny within 95% confidence (+/- 2 SEM).
  - **Claim:**