# Unit 1: Chemistry of Life

**What's the big deal?**

The basis of living organisms, and the heritable information they contain, is a collection of atoms and molecules linked together by chemical bonds that are organized in a hierarchy of structural levels that require constant input of energy.

*Pages 1-5 are meant to help highlight the important information included in each unit. While this can be a major source of information, make sure to use any/all studying tools available to you (ie class notes, textbook, videos, supplemental study books, etc.) Please note that while the College Board lays out the topics in this order, the class may go through the topics in a different order or combine similar topics.*

***Quiz date(s)***: _____ ***Test date***:_____

## Topic 0: Biology Review and an Introduction to Statistics

*The concepts in Topic 0 will be practiced throughout all 8 units*

### Learning Objective

To review the basic concepts of biology and statistics, as it relates to the course.

### Essential Knowledge

1. Identify or pose a testable question based on an observation, data, or a model.
2. State the null and alternative hypotheses, or predict the results of an experiment.
3. Identify experimental procedures that are aligned to the question, including:
    a. Identifying dependent and independent variables.
    b. Identifying appropriate controls.
    c. Justifying appropriate controls.
4. Support a claim with evidence from biological principles, concepts, processes, and/or data.
5. Provide reasoning to justify a claim by connecting evidence to biological theories.
6. Explain the relationship between experimental results and larger biological concepts, processes, or theories.
7. Construct a graph, plot, or chart.
8. Describe data from a table or graph, including:
    a. Identifying specific data points.
    b. Describing trends and/or patterns in the data.
    c. Describing relationships between variables.
9. Perform mathematical calculations.
10. Use confidence intervals and/or error bars (both determined using standard errors) to determine whether sample means are statistically different.

### Vocabulary/Review Questions

| | | | |
|---|---|---|---|
| Scientific method | Hypothesis (Null vs Alt) | Control group (neg vs pos) | Experimental group |
| Independent variable | Dependent variable | Constants | Statistics |
| Descriptive statistics | Inferential statistics | Central tendencies | Mean |
| Median | Mode | Variability | Range |
| Standard deviation | Standard error | Chi-Square | |

1. What are the 6 general steps of the scientific method?
2. How are hypotheses formulated?
3. What is the difference between null and alternative hypotheses? Do you always need both?
4. How do researchers determine their independent and dependent variables? How are they often graphed (ie what is on the x-axis what is on the y-axis)?
5. Are constants the same as controls? Why or why not?
6. When should a positive control be used? When should a negative control be used?
7. Describe central tendencies. Identify when each type of central tendency should be used.
8. What is used to measure variability?
9. Is data more reliable with low or high standard deviation? Why?
10. Why do researchers use SEM?
11. If standard error bars overlap, is the difference between the means significantly different? Why or why not?

YouTube playlist with review videos for Topic 01 stats:

## Topic 1: Structure of Water and Hydrogen Bonding

### Learning Objective

1.1.A: Explain how the properties of water that result from its polarity and hydrogen bonding affect its biological function.

### Essential Knowledge

1.1.A.1: Living systems depend on the properties of water to sustain life.

i. Water has polarity, because of the formation of polar covalent bonds between hydrogen and oxygen within water molecules. This polarity contributes to hydrogen bonding between and within biological molecules
ii. Water has a high specific heat capacity, which allows for the maintenance of homeostatic body temperature within living organisms.
iii. Water has a high heat of vaporization, which allows for the evaporative cooling of the surrounding environment. In living organisms, this property allows for body temperature to be maintained.

1.1.A.2: The hydrogen bonds between adjacent polar water molecules result in cohesion, adhesion, and surface tension.

YouTube playlist with review videos for Topic 1:

### Vocabulary/Review Questions

| | | | |
|---|---|---|---|
| Matter | Element | Electronegativity | Atomic number |
| Atomic mass | Octet rule | Chemical bonds | Compound |
| Covalent bonds | Nonpolar covalent bonds | Polar covalent bonds | Ionic bonds |
| Adhesion | Cohesion | Capillary action | Solvent |
| Solution | Solute | pH (acid vs base) | Buffer |

1. Identify the elements that make up nearly all living matter.
2. Differentiate between a solute, solvent, and solution.
3. Describe covalent bonds and give two examples.
4. Describe ionic bonds and give two examples.
5. How are hydrogen bonds different from other types of bonds?
6. Draw a few water molecules. Label the types of bonds found in and between the molecules.
7. How does electronegativity affect the interactions between water molecules?
8. Imagine if O and H had the same electronegativity, what would that do to the properties of water?
9. Describe the properties of water; give an example of each.
10. Describe two ways in which the properties of water benefit organisms.

## Topic 2: Elements of Life

### Learning Objective

1.2.A: Describe the composition of macromolecules required by living organisms.

### Essential Knowledge

1.2.A.1: Atoms and molecules from the environment are necessary to build new molecules. Carbon, hydrogen, and oxygen are the most prevalent elements used to build biological molecules such as carbohydrates, proteins, lipids, and nucleic acids. Additionally:

i. Sulfur is used in the building of proteins.
ii. Phosphorus is used in the building of phospholipids (a type of lipid) and nucleic acids.
iii. Nitrogen is used in the building of nucleic acids.

### Vocabulary/Review Questions

| | | | |
|---|---|---|---|
| Functional groups | Organic chemistry | Organic compounds | Hydrocarbons |
| | Macromolecule | | |

1. Draw the chemical formula for these functional groups: hydroxyl, carbonyl, carboxyl, amines, and phosphate.
2. What makes carbon such a versatile element?
3. How do functional groups affect the structure and behavior of organic molecules?
4. What is the difference between hydrocarbons and other organic molecules?

## Topic 3: Introduction to Macromolecules

Learning Objective

1.3.A: Describe the chemical reactions that build and break biological macromolecules.

Essential Knowledge

1.3.A.1: Hydrolysis is a chemical reaction involving the cleaving of covalent bonds. This type of reaction breaks down molecules into smaller molecules. When water is added to the bond between monomers in a polymer, the bond is broken. The hydrogen ion from a water molecule is added to one monomer and the hydroxyl group of the water molecule is added to the other monomer, completing the reaction.

1.3.A.2: Dehydration synthesis occurs when two smaller molecules are joined together through covalent bonding. A hydrogen ion is removed from one monomer and a hydroxyl group is removed from the other. This causes the loss of the equivalent of a water molecule from the reactants and the connection of the two remaining monomers. The connection of many monomers is known as polymerization.

YouTube playlist with review videos for Topics 2 and 3:

Vocabulary/Review Questions

| | | | |
|---|---|---|---|
| Dehydration reaction | Hydrolysis | Polymers | Monomers |

1. Differentiate between a hydrolysis and a dehydration reaction.
2. Draw an example of a hydrolysis reaction and a dehydration reaction.

## Topic 4: Carbohydrates

Learning Objective

1.4.A: Describe the structure and function of carbohydrates.

Essential Knowledge

1.4.A.1: Monosaccharides (simple sugars) are the monomers for polysaccharides (complex carbohydrates). These monomers are connected by covalent bonds to form polymers such as complex carbohydrates, which may be linear or branched.

Vocabulary/Review Questions

| | | | |
|---|---|---|---|
| Disaccharide | Starch | Monomer | Cellulose |
| Polymer | Monosaccharide | Polysaccharide | Glycogen |
| Glycosidic linkage (from case study) | | | |

1. What are polysaccharides? What are their monomers?
2. What important roles do polysaccharides play in animals? Plants?

## Topic 5: Lipids

Learning Objective

1.5.A: Describe the structure and function of lipids.

Essential Knowledge

1.5.A.1: Lipids are typically nonpolar, hydrophobic molecules whose structure and function are derived from the way their subcomponents are assembled. Fatty acids can be described as either saturated or unsaturated.

i. Saturated fatty acids contain only single bonds between carbon atoms.
ii. Unsaturated fatty acids contain at least one double bond between carbon atoms, which causes the carbon chain to kink.
iii. The more double bonds in a fatty acid tail, the more unsaturated the lipid becomes.
iv. The more unsaturated a lipid is, the more liquid it is at room temperature.

1.5.A.2: Lipids provide a variety of functions for living organisms. Some examples of lipids are fats, steroids including cholesterol, and phospholipids.

i. Fats provide energy storage and support cell function. In some cases, they can also provide insulation to help keep mammals warm.
ii. Steroids are hormones that support physiological functions including growth and development, energy metabolism, and homeostasis.
iii. Cholesterol provides essential structural stability to animal cell membranes.
iv. Phospholipids group together to form the lipid bilayers found in plasma and cell membranes.

Vocabulary/Review Questions

| | | | |
|---|---|---|---|
| Lipid | Fat | Fatty acid | Phospholipid |

1. Draw a phospholipid. Label all parts, including polar and nonpolar regions.
2. Phospholipids play a major role in cells. Where can they be found in a cell, and what is their role?
3. How does saturation affect fatty acid structure/function

## Topic 6: Nucleic Acids

Learning Objective

1.6.A: Describe the structure and function of DNA and RNA.

Essential Knowledge

1.6.A.1: In nucleic acids (DNA and RNA), biological information is encoded in sequences of nucleotide monomers. Each nucleotide has the following structural components: a five-carbon sugar (deoxyribose or ribose), a phosphate, and a nitrogenous base (adenine, thymine, guanine, cytosine, or uracil).

1.6.A.2: Nucleic acids have a linear sequence of nucleotides that have ends, defined by the 3'(three prime) hydroxyl and 5' (five prime) phosphates of the sugar in the nucleotide. During nucleic acid synthesis, nucleotides are added to the 3' end of the growing strand, resulting in the formation of covalent bonds between nucleotides.

→ ***Continued on next page***

Vocabulary/Review Questions

| | | | |
|---|---|---|---|
| Antiparallel | DNA | RNA | Nucleotide |
| Nucleic acid | Gene | Pyrimidine | Purine |

1. What forms the "backbone" of DNA?
2. What does it mean that DNA is antiparallel?
3. Why are DNA strands antiparallel? (i.e., why can't both strands run in the same direction?
4. Identify the three components of a nucleotide.
5. What is the monomer called if it is lacking a phosphate group?
6. List the possible nitrogenous bases that can be found in nucleotides.
7. Compare and contrast DNA and RNA.
8. Where can DNA be found in a cell? What about RNA?
9. What functional group defines the 5' end?
10. What functional group defines the 3' end?
11. How many bonds connect adenine and thymine? How does this differ from cytosine and guanine?

1.6.A.3: DNA is structured as an antiparallel double helix, with two strands of nucleotides running in opposite 5' to 3' orientation. In DNA, adenine nucleotides pair with thymine nucleotides via hydrogen bonds (A-T), and cytosine nucleotides pair with guanine nucleotides via hydrogen bonds (C-G). In RNA, adenine pairs with uracil (A-U).
1.6.A.4: Structural differences between DNA and RNA include:

i. DNA contains the sugar deoxyribose, and RNA contains the sugar ribose.
ii. DNA contains the nitrogenous base thymine, and RNA contains the nitrogenous base uracil.
iii. DNA is typically double stranded, while RNA is typically single stranded.

## Topic 7: Proteins

Learning Objective

1.7.A: Describe the structure and function of proteins.

Essential Knowledge

1.7.A.1: Proteins comprise linear chains of amino acids connected by the formation of covalent (peptide) bonds that form between a carboxyl group (--COOH) of one amino acid and an amine group (--$NH_2$) of the next amino acid, resulting in a growing peptide chain.
1.7.A.2: Amino acids are composed of a central carbon atom with a hydrogen atom, a carboxyl group, an amine group, and a variable R group covalently bound to it. The R group of an amino acid can be categorized by three possible chemical properties: hydrophobic/nonpolar, hydrophilic/polar, or ionic. The interactions of these R groups determine the structure and function of that region of the protein.
1.7.A.3: The specific sequence of amino acids in proteins determines the primary structure of a polypeptide as well as the overall shape of the protein.
1.7.A.4: Secondary structures of proteins are made through the local folding that forms from interactions between atoms of the polypeptide backbone of the amino acid chain. Hydrogen bonding forms shapes such as alpha-helices and beta-pleated sheets.
1.7.A.5: The three-dimensional shape of the tertiary structure of a protein results from the formation of hydrogen bonds, hydrophobic interactions, ionic interactions, or disulfide bridges.
1.7.A.6: The quaternary structure arises from interactions between multiple polypeptides. All four levels of a protein structure determine the function of a protein.

YouTube playlist with review videos for Topics 3-7:

Vocabulary/Review Questions

| Primary structure | Secondary structure | Tertiary structure | Quaternary structure |
|---|---|---|---|
| Protein | Amino acid | | |

1. What determines the primary structure of a protein?
2. How does the primary structure of a protein affect the other structural levels?
3. Would the function of a protein change if the amino acid sequence changed? Why or why not?
4. What interactions occur in the secondary structure? Tertiary structure? Quaternary structure?
5. True/false: a change in a protein's structure will change the protein's function?
6. How many monomers of proteins are there?
7. Draw the general structure of an amino acid.
8. How do the R groups of amino acids contribute to protein structure?

**Welcome to AP Biology ☺**

**AP Biology**

Throughout this course you will study core scientific principles, theories, and processes that govern living organisms and biological systems.

The course is broken down into _____ _____ (skills) and _____.

**AP Biology Science Practices**

The Science Practices are skills that you are expected to develop and apply throughout the course.

- The Science Practices include:
  - Concept explanation
  - Analyze visual representations
  - Determine scientific questions and methods
  - Represent and describe data
  - Perform statistical tests and data analysis
  - Develop and justify scientific arguments using evidence

**AP Biology Big Ideas**

The content covered in AP biology is broken down into four Big Ideas:

- Big Idea 1: _____- the process of evolution drives the diversity and unity of life
- Big Idea 2: _____- biological systems use energy and molecular building blocks to grow, reproduce, and maintain dynamic homeostasis.
- Big Idea 3:_____- living systems store, retrieve, transmit, and respond to information essential to life processes.
- Big Idea 4: _____- biological systems interact, and these systems and their interactions exhibit complex properties.

The Big Ideas serve as the foundation of the course and are further broken down into:

- _____ _____: define what a student needs to be able to do with the content knowledge in order to progress toward the enduring understandings
- _____ _____: describe the knowledge required to perform the learning objective

*These are listed at the front of your notes for your reference*

**AP Biology Units**

This course will cover 8 units:

- Unit 1: Chemistry of Life (Big Ideas 2-4)
- Unit 2: Cell Structure and Function (Big Ideas 1,2,4)
- Unit 3: Cellular Energetics (Big Idea 2)
- Unit 4: Cell Communication and Cell Cycle (Big Ideas 2,3)
- Unit 5: Heredity (Big Ideas 1,3,4)
- Unit 6: Gene Expression and Regulation (Big Idea 3)
- Unit 7: Natural Selection (Big Ideas 1,4)
- Unit 8 Ecology (Big Ideas 1-4)

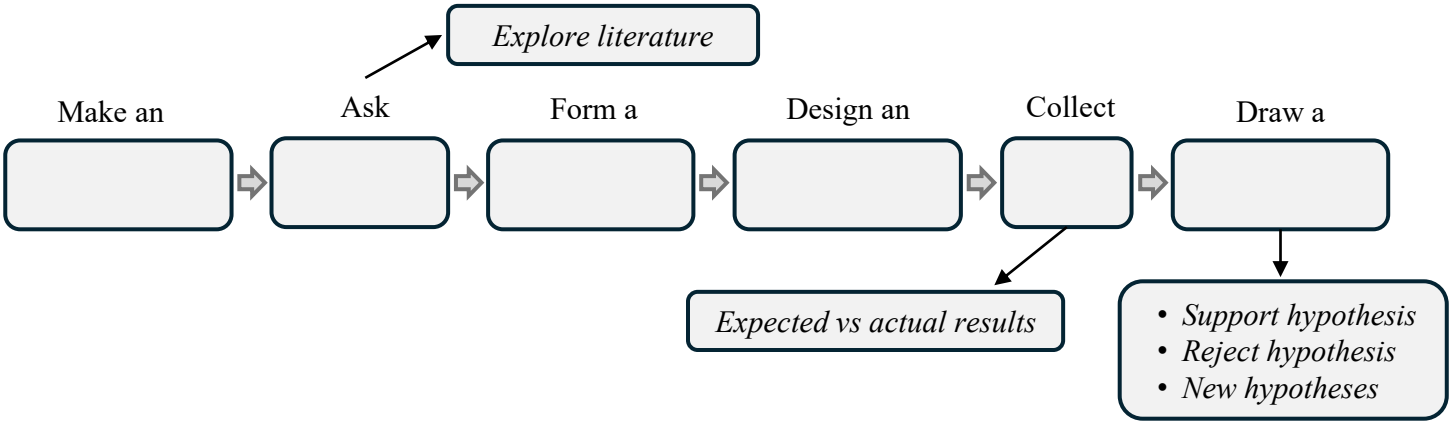
*Notice*: the Big Ideas in each unit overlap and build on each other

**Meaning** what you learn in each unit cannot be forgotten because it is important for other units too!

How can knowing this guide your study throughout the year?

## Scientific Method

**Scientific method**: a step-by-step process used by scientists to investigate _____, gather _____, and draw _____ based on experiments and observations.




## Make an Observation

Observation: monarch butterflies can sometimes be found flying at night near very bright, artificial sources of light (like streetlights).

## Ask Questions

- What could be causing this phenomenon?
    - Can this be manipulated and turned into a _____ experiment
    - Explore the literature:
        - *Monarch butterflies are diurnal (active/flying during the day; resting/not flying at night)*
        - *Circadian rhythm (internal clock tracks day/night)*
        - *Migratory (use sunlight as a compass; antennae help track the sun during flight)*
        - *Proteins important for flight are processed at night while the butterfly rests*
- Scientific questions the researchers might investigate:

## Forming Hypotheses

- Hypothesis: a _____ explanation for an _____
    - Explains the relationship _____ variables and what the researcher _____ to happen to one variable if another variable _____

➔Questions?
➔Textbook chapters/pages to review

- You may have previously learned this structure: heard as: "If … , then … (because…)" but does **not** need to be in this format
  - "If" – the _____ variable
  - "Then" – the _____ variable
  - "Because" – optional _____
- Results can either _____ or _____/_____ the hypothesis
  - NEVER SAY:

Think, Pair, Share

Let's go back to the monarch butterfly example

- *Scientific question being investigated: How does exposure to artificial light at night affect the number of monarch butterflies that initiate flight*
  - What is a possible hypothesis for this question?

**Hypothesis Testing- Stats**

- Hypothesis tests: statistical test procedures to test hypotheses about a _____ based on a _____
  - Helps to determine if observed differences between groups are statistically _____ or due to _____

Involves two types of hypotheses:

- Null hypothesis ($H_0$)
  - Hypothesis that there is ____ _____ or ____ _____ between the two groups of data
  - Observations are the result of _____
- Alternative hypothesis ($H_a$: $H_1$, $H_2$…etc.)
  - Hypothesis that there _____ a relationship/ effect/ difference between the two groups of data
  - Observations are due to a _____ cause

*New term for what you are <u>already</u> familiar with. This is what the researchers are claiming/studying*

➔Questions?
➔Textbook chapters/pages to review

- Why do we need a null for hypothesis testing?
    - Provides a _____, which we can use to _____ our sample results to
- Allows for a hypothesis to be tested in a meaningful way using _____ tests.
    - Use the data to determine if there is strong enough evidence to _____ the _____ hypothesis, meaning the _____ hypothesis is _____ by the data (we will learn more about this in Unit 5)

**Practice**

*Answer the questions below using the space provided.*

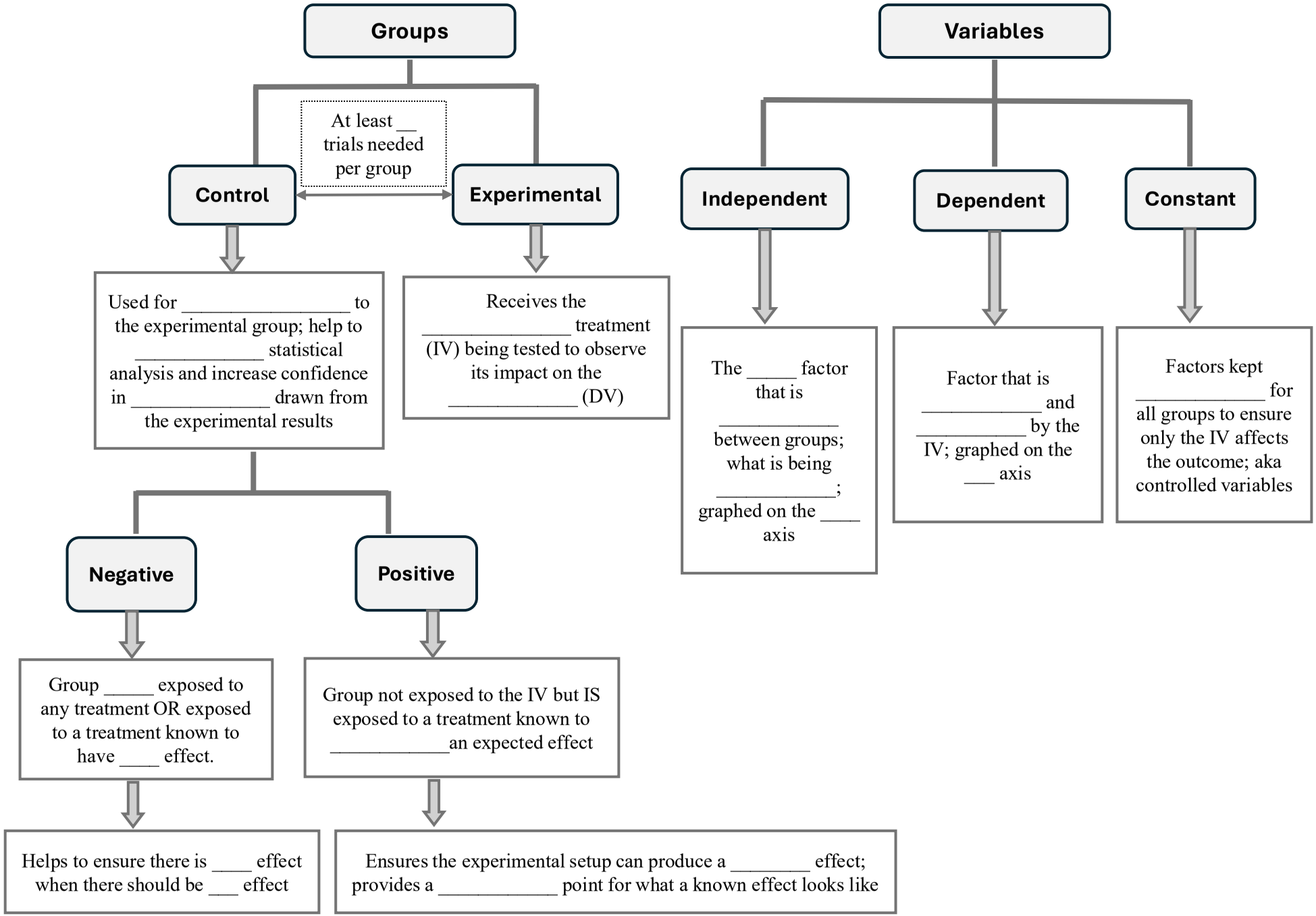
1. Determine a suitable null hypothesis for the monarch butterfly experiment.

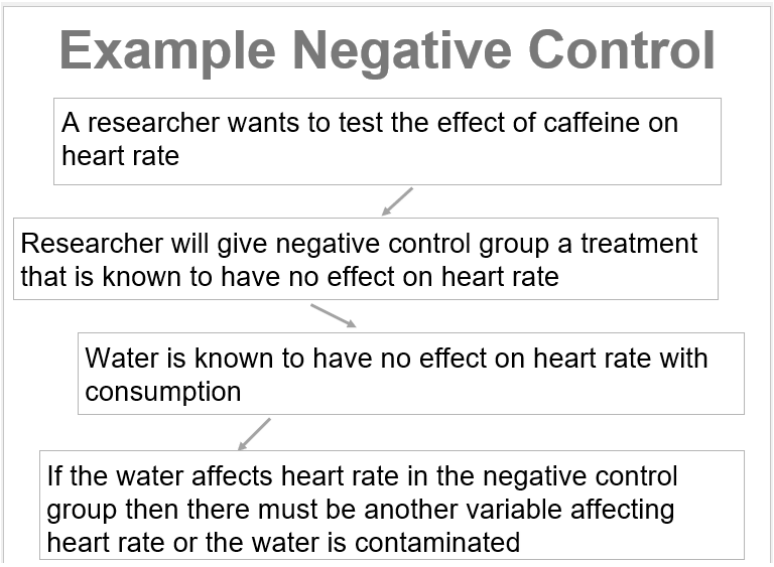
2. Does ivy grow better in areas with more sun versus in shady areas? Formulate one null ($H_0$) and one alternative ($H_1$) hypothesis.

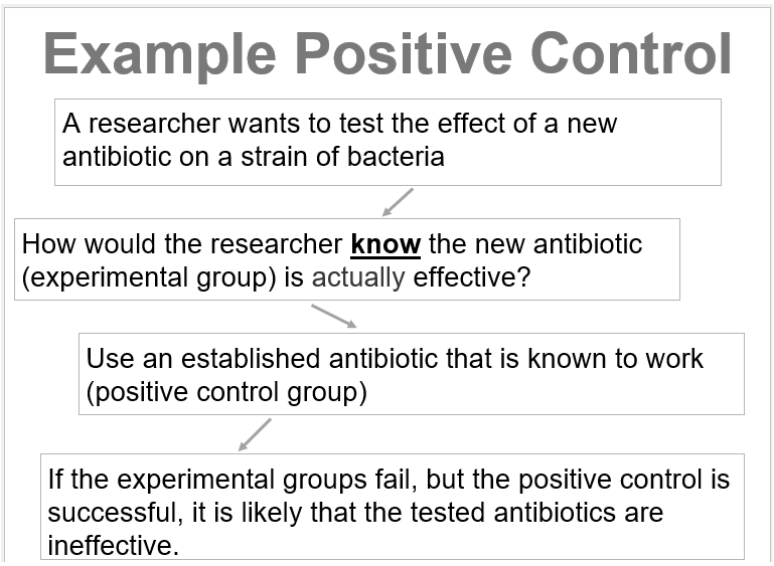
3. A group of students are interested in examining the potential effects of caffeine (from soda) on heart rate. One group of students hypothesizes that soda consumption will not have an effect on heart rate, while another group proposed an alternative hypothesis that soda consumption will increase heart rate. What data would be expected if the alternative hypothesis was supported?

4. A researcher suggests that small doses of hyaluronic acid (HA) will promote the uptake of water in human skin, thus reducing symptoms of dryness and dehydration. He suggests that HA binds to water and prevents it from evaporating off of the skin. The researcher creates a skin cream formulated with HA and compares the skin of 100 people before and after use of the cream. Formulate one null ($H_0$) and one alternative ($H_1$) hypothesis. Describe the data you would expect to see that would support the null hypothesis.

# Experimental Design






Think, Pair, Share

1. Why is it important to ONLY change the independent variable?

2. What is a bias? How can a bias affect an experiment?

➔Questions?
➔Textbook chapters/pages to review

**Practice: Variables**

*Read the problem below and identify the independent and dependent variables.*

1. You are washing cars to earn money. For each car you wash, you earn $10.

2. You are interested in how stress affects heart rate in humans. You place humans under different levels of physical stress and measure their heart rate.

3. A researcher is studying warning calls in a rare species of birds native to South America. The researcher is interested in the reactions of surrounding birds when the warning call is given.

4. A scientist believes that fish can swim faster in warmer water versus in cooler water.

## Practice: Control Groups

1. You want to design an experiment to determine if a new drug has an impact on lowering blood pressure. Test subjects with high blood pressure are given a new medication in pill form. The percentage of patients whose blood pressure decreased is measured. What are good positive and negative controls?

2. You believe that when someone drinks a soda, their heart rate will increase. You set up an experiment, using various sodas, and various amounts of consumption and then measure the heart rate of the individuals. What are good positive and negative controls?

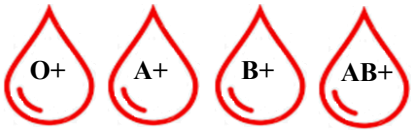
3. Proper soil composition is important for plants. Some elements, like nitrogen, are known to increase plant growth. A researcher wants to develop a soil with added minerals and nutrients to determine the best composition to promote healthy plant growth. What are good positive and negative controls?

4. Approximately 10% of people living in the United States are allergic to penicillin. A research team has developed a new antibiotic that could potentially replace penicillin and treat a wide variety of bacterial infections. To test their theory, the scientists grow *Streptococcus pyogenes* in petri dishes. *S. pyogenes* causes numerous infections in humans, like pharyngitis, tonsillitis, and scarlet fever. These diseases are normally treated successfully with penicillin. They expose *S. pyogenes* to their new strain of antibiotic to determine its effectiveness. What are good positive and negative controls?

## Experimental Design Review: Catch the Errors

Read the experimental design below. For each section there are errors in the experimental design: 1) Identify what was done **incorrectly** and 2) Correct what was done incorrectly.

1. An experiment is designed to see if mosquitoes choose prey based on blood type. The researcher chooses 4 blood types to investigate: O+, A+. B+, AB+




The researcher formulates the following null and alternative hypotheses:

- $H_0$: There will be differences in mosquito preferences among the blood types (O+, A+, B+, AB+)
- $H_1$: mosquitoes will have a preferred blood type.

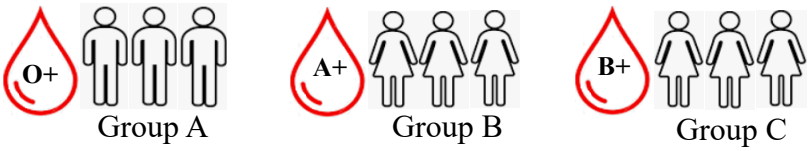
*Write your responses in the space below*

a. Identify what was done incorrectly.

b. How can this be corrected?

---

Next, individuals are chosen who will participate in the experiment. Each group has 3 individuals who are approximately the same age, height, weight, and blood type.




a. Identify what was done incorrectly.

b. How can this be corrected?

---

Participants from each group placed their right arm into a container with mosquitoes for the same amount of time. Each container was identical and housed the same number of mosquitoes. Due to an air conditioning issue in the lab, however, the room for the B+ group was warmer than the others.

a. Identify what was done incorrectly.

b. How can this be corrected?

---

The total number of bites per group over the course of ten minutes were recorded to determine if there is a blood type preference among the mosquitoes being studied. The data obtained indicated that group O+ had a significantly highest number of bites. The researchers concluded that their hypothesis was correct.

a. Identify what was done incorrectly.

b. How can this be corrected?

## Experimental Design Review

2. You want to design an experiment to see if birds will choose feeders based on color. You choose 3 colors for the bird feeders: purple, red, and blue. With this statement, fill in the following blanks:

Hypotheses:

- Null ($H_0$) hypothesis:

- Alternative ($H_1$) hypothesis:

Variables:

- Independent variable:

- Dependent variable:

Constants and controls:

- Enviornmental conditision that should be controlled for (constants)--*list as many that you can think of*:

- Controls (negative/positive):

## Introduction to Statistics in AP Biology

**Think, Pair, Share**

Read the two statements below, then answer the questions:

A. "The earlier you start reviewing, the better you are likely to do on the AP Bio exam."

B. "On average, I watch an hour of TV per day."

1. Which statement is generalizing, and which is summarizing?

2. Which statement makes a prediction?

3. How might these statements relate to statistics?

**Statistics**

- **Statistics**: methods used to _____, _____, or _____ quantitative data
  - Statistics in biology helps us understand important information by:
    - _____ our observations
    - Making _____ based on the summary
  - Also helps scientists to:
    - Avoid jumping to _____
    - Be cautious about _____

**Descriptive Statistics**

- Methods used to _____ or describe observations/samples
  - Measures of _____ _____:
    - *Mean, median, mode*
  - Measures of _____:
    - *Range, standard deviation*, variance, skewness, quartiles

**Inferential Statistics**

- Using observations to make estimates or _____; generalizing from a sample to a wider _____
  - *Standard error of the mean, confidence intervals*
  - Hypotheses tests:
    - _____ _____, ANOVA, t-test…

➔Questions?
➔Textbook chapters/pages to review

**Guided Example**

To review the stats required for AP Bio, let's look at a garden spider experiment

Researchers are studying a population of orb weavers in Southwest Michigan.

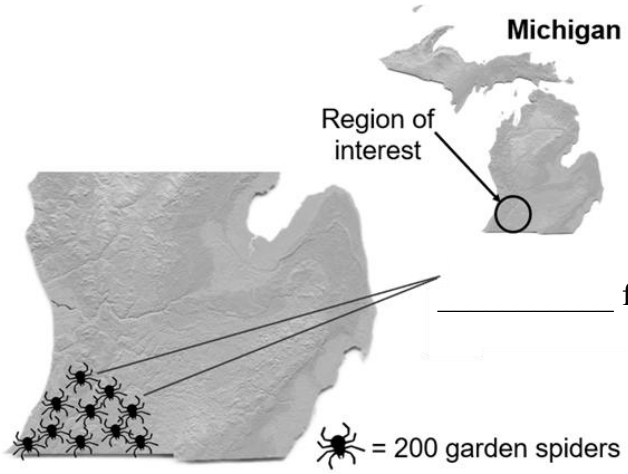
- Observation: the _____ of webs changes between seasons
- Scientific question: How does mating season affect the _____ of orb weaver _____?

Think, Pair, Share

Complete the null hypothesis for this experiment by filling in the blanks:

- Null Hypothesis ($H_0$): mating season has _____ _____on the average diameter of orb weaver webs.
- Alternative hypothesis ($H_1$): mating season will affect the average diameter of orb weaver webs.

➢ Question: There are an estimated 2,000 orb weavers within the area being studied. Do you think the researchers will measure the web diameters for all 2,000 spiders?

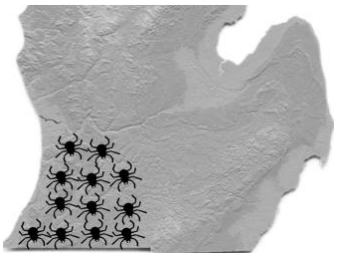



_____ from the _____

- Sample: a _____, _____ group selected from the population
  - In the spider study, maybe 30 randomly chosen individuals will be selected to measure web diameter
- Population: _____ members of the group being studied
  - In the spider study, this is all 2,000 spiders
- Researchers study a _____ and use _____ to make _____ about the _____

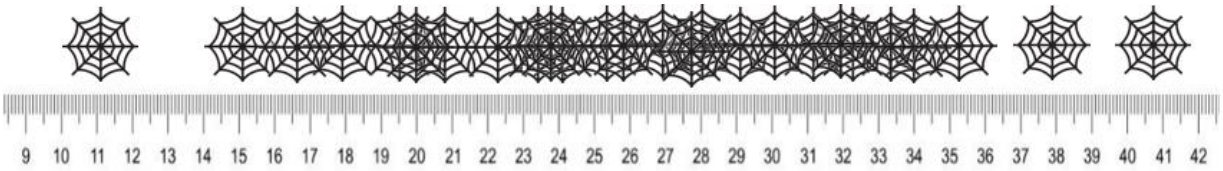
➔Questions?
➔Textbook chapters/pages to review

We can make a table to record our data



How can the _____
of the data be visualized better?

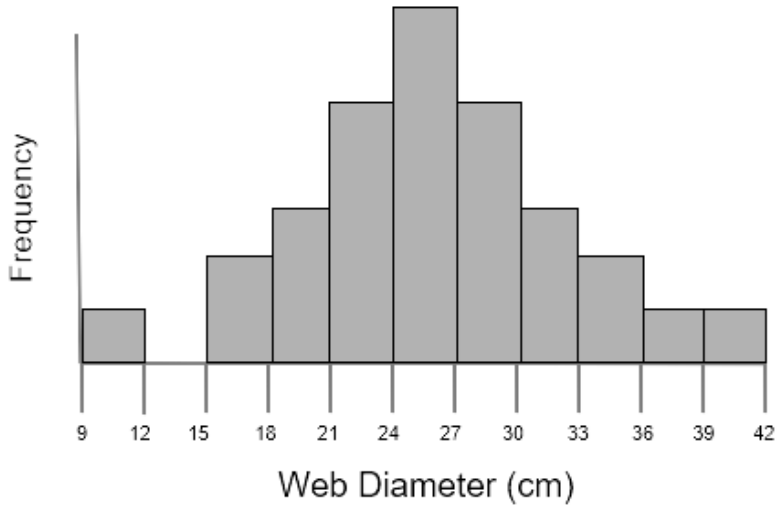
| | | | | | |
|---|---|---|---|---|---|
| 16.8 | 26.7 | 31.2 | 34.1 | 19.5 | 40.8 |
| 11.1 | 15.1 | 37.8 | 35.3 | 22.6 | 18.0 |
| 19.3 | 21.2 | 23.3 | 24.2 | 26.9 | 25.5 |
| 26.7 | 29.8 | 30.0 | 32.9 | 24.6 | 27.8 |
| 28.1 | 32.3 | 27.5 | 24.0 | 23.6 | 25.1 |




Diameter of web (cm)

To better visualize the _____ (shape) of the data, we can make a _____

1. Set up _____ (uniform _____ size that cover the entire range of the data)
2. Determine how _____ values go into each bin
3. Add bars: the _____ of each bar represents the _____/_____ of occurrences within each bin




We can describe the data distribution by its _____, its _____, and its _____

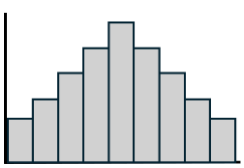
➔Questions?
➔Textbook chapters/pages to review

**SHAPE**

To describe the shape of the distribution, we look for:

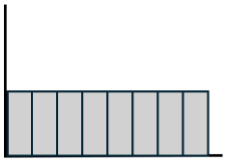
- Symmetry or skewness
- Number of peaks/_____ (unimodal, bimodal, multimodal)

Distributions we may encounter in this course include:



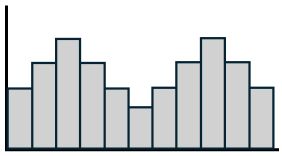
Normal

- *Symmetric, unimodal*



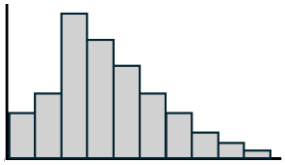
Uniform

- *Symmetric, all outcomes equally likely*



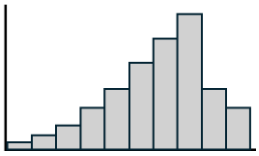
Bimodal

- *Symmetric, two modes (*can also be skewed*)*



Positive (right) Skewed

- *Right skewed, unimodal*

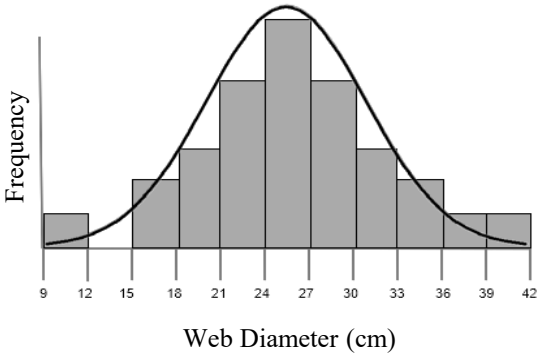


Negative (left) Skewed

- *Left skewed, unimodal*

Let's go back to our spider web data

- We can draw a _____ to help describe the _____

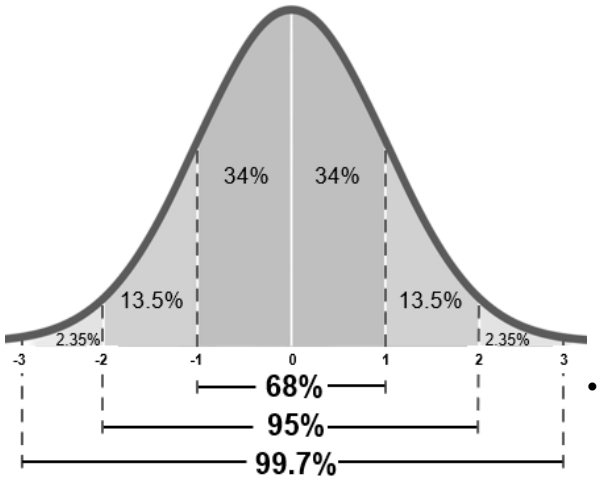



- Both the _____ and _____ tell us important information about our data
  - *What measurements are most likely*
  - *What measurements are least likely*

➢ In this example, the data is _____ _____ distributed

**Normal Distribution**

- _____ distribution of values for a population
- Described using the _____ and _____ _____ (spread)




- In a normal distribution:
  - _____% of the data falls within +/-1 standard deviation
  - _____% of the data falls within +/-2 standard deviations
  - _____% of the data falls within +/-3 standard deviations
- Most biological examples in this course will follow an approximately _____ distribution

- Understanding the shape of our distribution, helps us to make decisions about the best way to describe the _____ and _____ of our data (*discussed next*)

## CENTER

Central Tendencies: the center can be described by the _____, _____, and _____

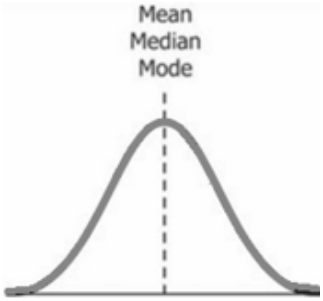
- *Mean: the average of the data set*
  - *Disadvantage: sensitive to outliers*
- *Median: the middle number in a range of data points*
  - *To solve: arrange the data points in numerical order. The middle number is the median. If there is an even number of data points, average the two middle numbers*
- *Mode: the value that appears most often*
  - *Only useful for categorical data (i.e., survey of favorite ice cream flavor) or when looking for the most common outcome*

Which measure of center to use, depends on the _____ of the distribution

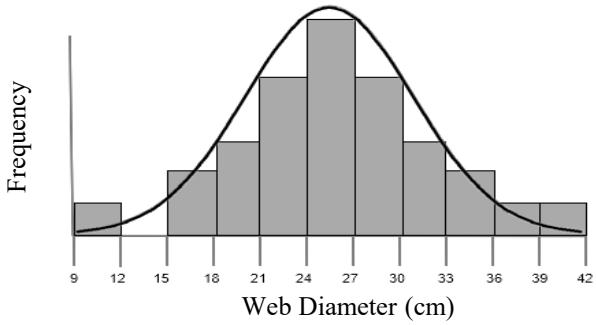
- *We will focus on normal and skewed distributions*

### Normal Distribution

- In a perfectly normal distribution: _____ = _____ = _____




- Most examples we will see in this course will be _____ normally distributed (like the data from web diameters)
  - In _____ normal distributions, the _____ is the preferred measure of central tendency




| | | | | | |
|---|---|---|---|---|---|
| 16.8 | 26.7 | 31.2 | 34.1 | 19.5 | 40.8 |
| 11.1 | 15.1 | 37.8 | 35.3 | 22.6 | 18.0 |
| 19.3 | 21.2 | 23.3 | 24.2 | 26.9 | 25.5 |
| 26.7 | 29.8 | 29.9 | 32.9 | 24.6 | 27.8 |
| 28.1 | 32.3 | 27.5 | 23.9 | 23.6 | 25.1 |

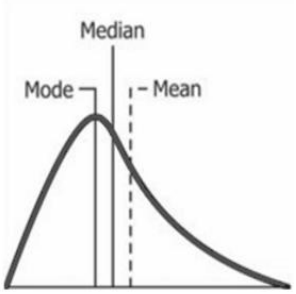
$$\bar{x} = \frac{16.8 + 26.7 + 31.2 + \ldots..}{30} = \boxed{\phantom{00}}$$

- Since we usually do not have the time, money, or capability to collect data for the _____ population, we will usually never know the _____ population mean. The _____ _____ serves as an _____ for the population mean

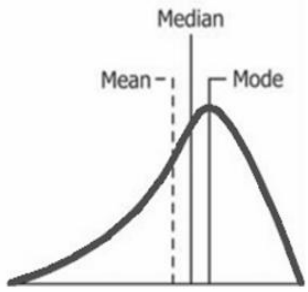
**CENTER**

**Skewed Distribution**

Mode < median < mean




Mean < median < mode



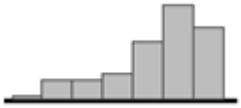

Notice that the _____ is the most affected by outliers

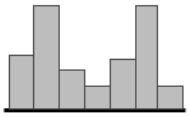
- In skewed distributions, the _____ will be the preferred measure of central tendency

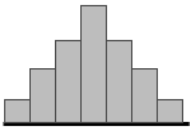
---

***Review: Shape and Center***

1. Examine the histograms below. Describe the shape of each distribution:







_____ _____ _____ _____

1. What are the three measures of central tendency?

2. Which measure of central tendency is best for data sets that have abnormal values (i.e., extreme high and low outliers)? Why?

3. Researchers are interested in how long students spend on homework per day. They take a random sample of 10 university students. They examine the average amount of time each student spends on homework over the course of a single day. The data is below:

| Student | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Time (min/day) | 38 | 120 | 70 | 22 | 258 | 46 | 84 | 20 | 64 | 90 |

For this data set determine the mean and median. Then identify which measure of center (mean/median) would be best for this data set.

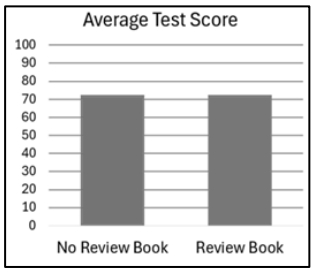
## VARIABILITY

The degree to which data are _____ _____ in a data set

- Variability helps to give a more _____ _____ of a distribution

**Example**

Based on the graph, did using a review book make a difference in test scores?




Two distributions, same _____, but different _____ of data

_____ students passed

| | | | | | | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No Review Book | 84 | 68 | 56 | 68 | 89 | 62 | 75 | 68 | 77 | 78 | **72.5** |
| Review Book | 73 | 73 | 72 | 71 | 77 | 72 | 70 | 74 | 71 | 72 | **72.5** |

_____ _____ students passed

Variability can be measured using _____, _____ _____, and _____

- *Remember: the shape of the distribution (normal or skewed) informs us how to best measure variability*

---

### *Normal Distribution*

---

- For approximately normal distributions, the spread can be described by _____

_____

  - Standard deviation: the _____ amount by which all the values deviate from the _____ (measures the _____ of the data)

***Formula***

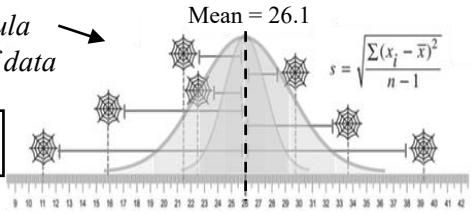
Sum of → Measured value

Standard deviation → $s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$ ← Mean

Degrees of freedom

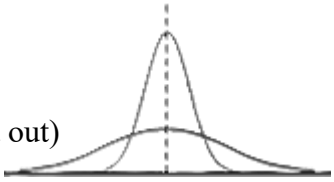
*Visual of how the formula measures the spread of data* →

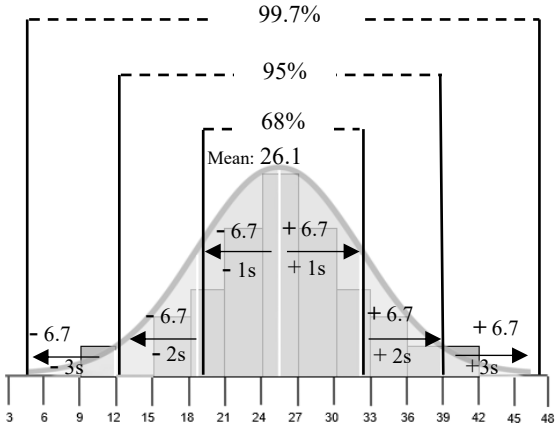
$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} = \square$$




Remember: this is a _____. The standard deviation for our sample provides an _____ that should reflect how the data are spread around the _____ mean

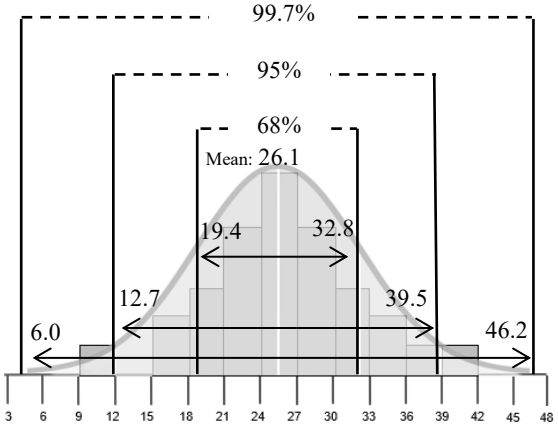
- Low (small) standard deviation: data is _____ to the mean
- High (large) standard deviation: data is _____ from the mean (more spread out)






- Mean ± 1 SD
- Mean ± 2 SD
- Mean ± 3 SD

Shows the values captured in each standard deviation →




➔Questions?

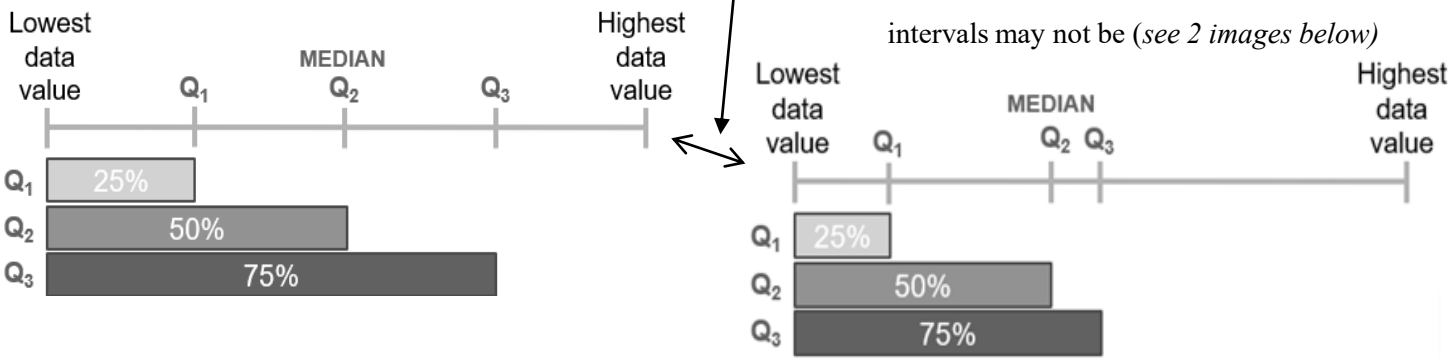
## VARIABILITY

### *Skewed Distribution*

- In non-normal distributions (e.g., skewed) the spread can be described by _____ (interquartile range)
  - Quartiles divide a data set into _____ *equal* parts
    - Quartiles are labelled Q1, Q2, and Q3

_____ are equal,

intervals may not be (*see 2 images below)*




- To find the IQR, we must first find the quartiles. Example data set:


| 4 | 7 | 7 | 16 | 4 | 10 | 10 | 2 | 50 | 14 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|

Arrange the data points in _____ order

| 2 | 4 | 4 | 7 | 7 | 7 | 10 | 10 | 14 | 16 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|

*Notice that because the line for Q2 is drawn through a number on the list, you exclude that value when finding the median of the lower/upper half of the data set*

Find the _____ = _____

*When there is an odd number in your data set, the median is the center value. Once you find the median, you draw a vertical line through that value*

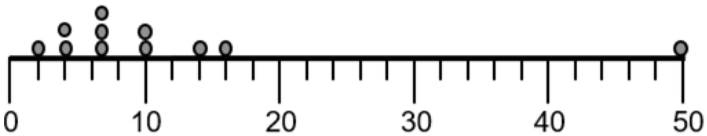
| 2 | 4 | 4 | 7 | 7 | 7 | 10 | 10 | 14 | 16 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|

Find the _____ of the lower half of the data =_____

Find the _____ of the upper half of the data =_____

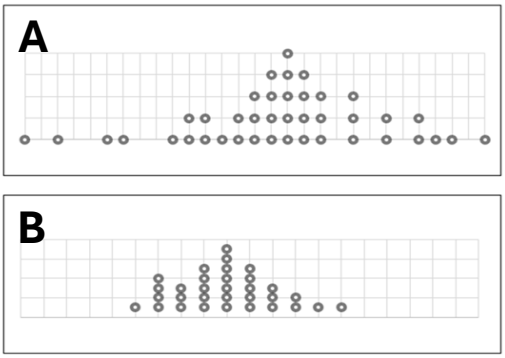
- Now that we have $Q_1$, $Q_2$, and $Q_3$, we can find the IQR
  - IQR measures the spread of the _____ _____% of a data set
    - To find the IQR: _____ – _____
    - IQR = 14 – 4 = _____
    - Can be represented as a box and whisker plot

*Draw and label the box and whisker plot*



***Review: Variability***

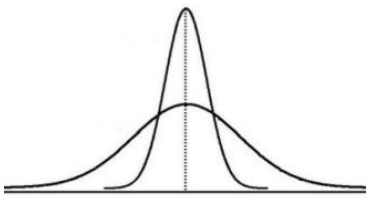
1. Which of the two distributions (A or B) do you think has a higher standard deviation? Why?




2. Which of the following options provides the most accurate description of standard deviation?
    1. The average of all data points
    2. The difference between the largest and smallest values in a data set
    3. The average distance all values deviate from the mean
    4. The value that occurs with the most frequency in a data set

3. True or False: two data sets can have the same mean, but different levels of variability.

4. Examine the graph below. Label the distribution with a high standard deviation as A and the distribution with a low standard deviation as B. Then explain how you were able to determine this.



5. You collect data on the number of eggs laid by a species of fly. Most of the flies lay approximately 20-30 eggs, but a few lay no eggs and a few lay over 100. Describe the shape of this distribution. Which measure of spread would be best: standard deviation or IQR? Why?

6. Which of the following options correctly defines IQR?
    1. $Q_1 - Q_3$
    2. $Q_3 - Q_1$
    3. $Q_2 - Q_1$
    4. $Q_1 - Q_2$

➔Questions?
➔Textbook chapters/pages to review

**Sampling Variation**

**Think, Pair, Share**

Will the sample be a perfect representation of the population? Justify your response with an explanation.

Different _____ from the same population of spiders, will give _____ results

 = 24.5 cm  = 30.1 cm  = 25.3 cm  = 28.7 cm

So how do we quantify the uncertainty of the sample? (how well does the sample represent the population?)

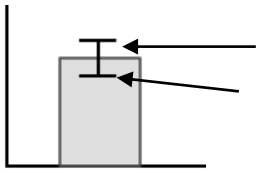
---

***Estimating Population Means***

**Confidence Intervals**

Confidence interval: a _____ of values in which we are 95% confident the _____ population mean will fall within (true population mean- diameter of all spider webs in Southwest Michigan)

- Built using the sample _____ and the _____ _____ of the mean



- Upper limit = Mean ___ 2 x SEM
- Lower Limit = Mean ____ 2 x SEM

- Standard error of the mean (SEM or $SE_{\bar{x}}$): is used to _____ how _____ the sample mean _____ the population mean
- Uses the standard deviation of the sample to estimate the variation in the population

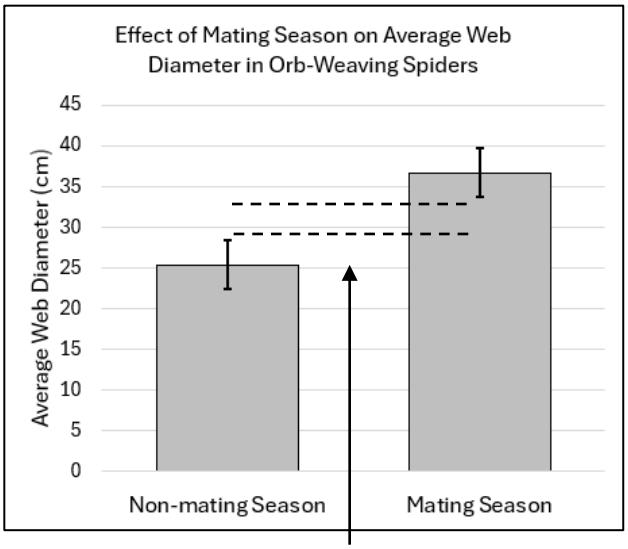
Standard error of the mean → $SE_{\bar{x}} = \frac{s}{\sqrt{n}}$ ← Standard deviation of sample; ← Size of the sample

**Think, Pair, Share**

Looking at the formula for standard error answer the following questions:

1. Circle the correct option: increases in sample size increase/decrease standard error.
2. Circle the correct option: increases in standard deviation increase/decrease standard error.

***Estimating Differences Between Population Means Using Confidence Intervals (+/- 2SE$_{\bar{x}}$)***



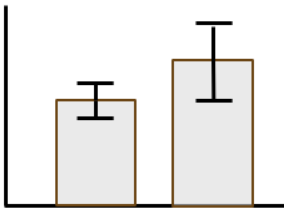

We can add our 95% confidence intervals (+/-2SEM) to our bar graph

Note: *while it is not necessary, labelling the upper/lower limits will help YOU make the graph, and also helps the AP exam reader to quickly grade your graph.*

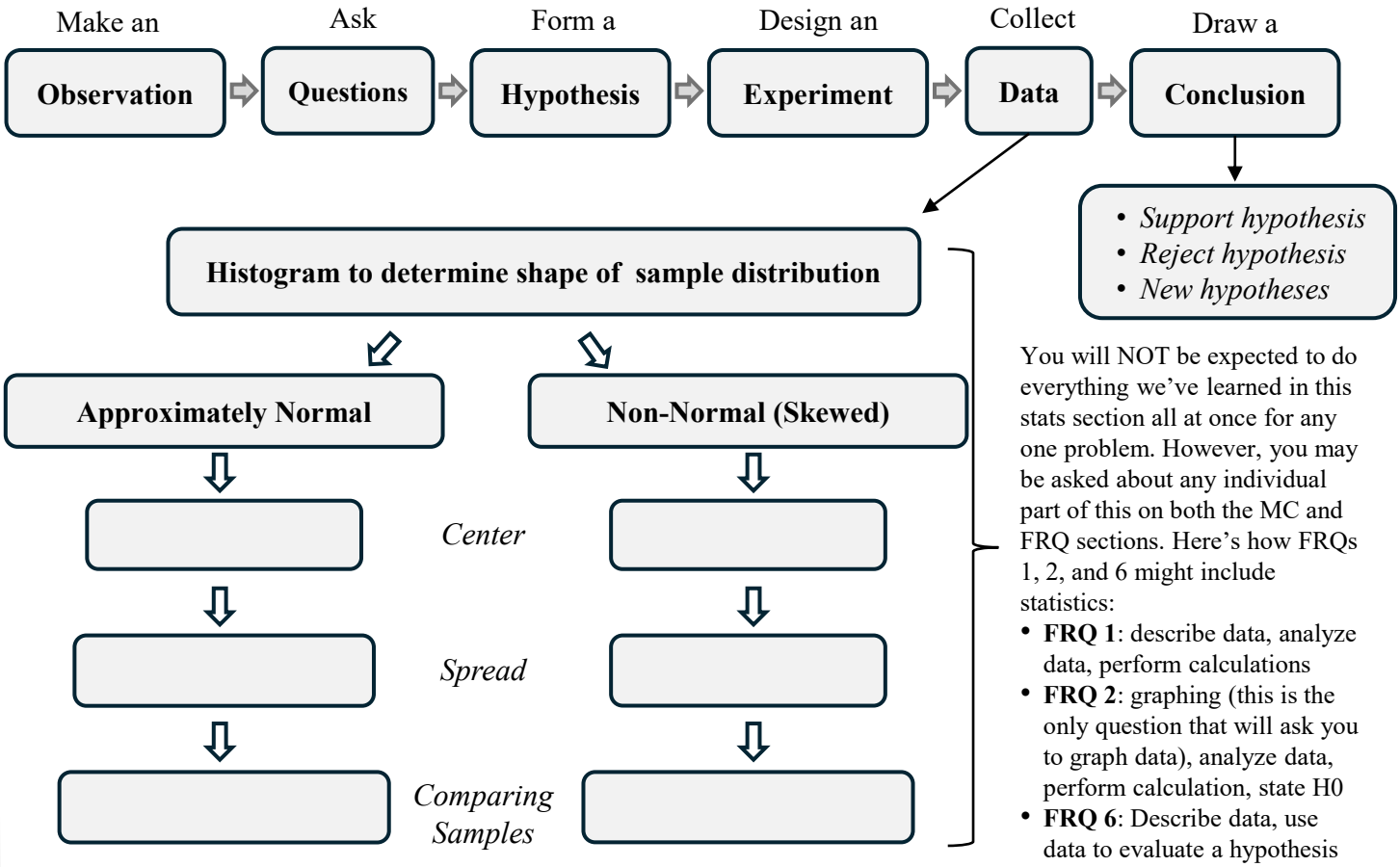
- For the spider web experiment: the error bars do _____ overlap
  - This means the researchers _____ the null hypothesis, and the _____ is supported
- There _____ a _____ _____ _____ between the mean web diameter of orb weavers in mating season and non-mating season
- These differences are likely due to a _____ cause

*What if there is overlap between the 95% CI?*

- There is _____ a statistically significant difference between the _____
- Observed differences are due to _____



***Summary of what we've learned:***




You will NOT be expected to do everything we've learned in this stats section all at once for any one problem. However, you may be asked about any individual part of this on both the MC and FRQ sections. Here's how FRQs 1, 2, and 6 might include statistics:

- **FRQ 1**: describe data, analyze data, perform calculations
- **FRQ 2**: graphing (this is the only question that will ask you to graph data), analyze data, perform calculation, state H0
- **FRQ 6**: Describe data, use data to evaluate a hypothesis

Examples of what you *might* be asked to do (FRQs 1, 2 and 6):

- Construct a graph (histogram, bar, line, box and whisker, log scale, dual y-axes, scatterplot, pie chart)
- Plot 95% CI (error bars) onto a bar graph using provided mean +/- 2 SEM
- Compare data sets by analyzing measures of spread (standard deviation or IQR)
- Compare different samples/treatments/groups by interpreting 95% CI (+/- 2 SEM) or compare samples by examining box and whisker plots
- Calculate the mean of a data set

**Goodness of Fit Test**

**Chi-square:** a form of statistical analysis used to compare the actual counts/frequencies (_____) with the _____ counts/frequencies

- Helps to:
  - Determine whether the _____ data provides a "good fit" to the observed data obtained
  - Determine if any _____ from the expected results are due to _____ _____ alone or to other circumstances (i.e., data collection error)
- Designed to analyze _____ data
- Use the equation to test the _____ hypothesis

Formula: $\chi^2 = \Sigma \left[ \frac{(\text{observed results} - \text{expected results})^2}{\text{expected results}} \right]$

*Chi Square will be covered in more depth in Unit 5 once we learn about genetics.*

## Statistics Practice Problems Part 1

**Directions**: Examine the data sets given in the problems below and answer their corresponding questions.

1. The University of Texas is interested in determining the average number of hours of sleep a pre-med major gets each night. They surveyed eight random individuals. The data is shown below:

| Individual | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| # of hours they slept the previous night | 6 | 4 | 7 | 7 | 6 | 5 | 7 | 6 |

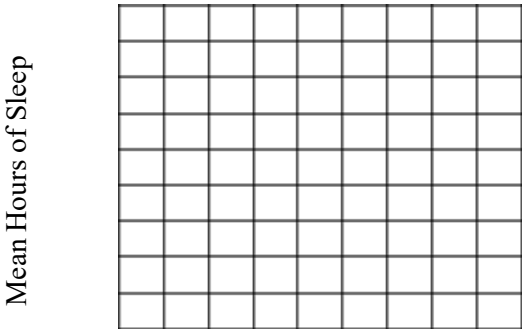
   a. Calculate the mean number of hours of sleep for this sample.

   b. The standard deviation for this sample is 1.07 hrs.

   c. Calculate the standard error of the mean for this sample (remember, once calculated multiply by 2 to get +/- 2 SEM). This is your 95% confidence interval, also known as an error bar.

   d. Use the space provided to make a bar graph for the mean number of hours slept and include an error bar.

Sleep Study of Pre-Med Majors




University of Texas Sample

   e. Harvard heard about the study being conducted by the University of Texas and decided to replicate it. The data is shown below. Without doing calculations, predict whether the data gathered by Harvard will have a higher or lower standard deviation than that of the University of Texas. Why?

| Individual | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| # of hours they slept the previous night | 3 | 5 | 7 | 8 | 6 | 11 | 2 | 12 |

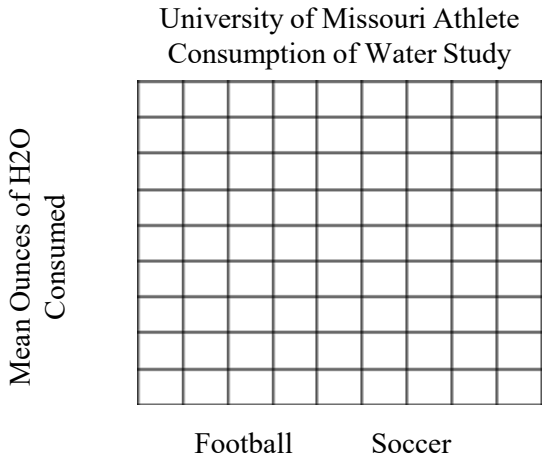
   f. OPTIONAL BONUS: now calculate the standard deviation for the data gathered by Harvard (in excel or on your calculator). Does it match your prediction?

2. An athletic trainer at the University of Missouri hypothesizes that football players drink more water than soccer players during the season, so he sends out a survey to test his hypothesis. The athletes were asked to record how many ounces of water they consumed over the course of one full day. The data for the athletes is below:

| | Average Ounces of $H_2O$ Consumed ± $2SE_x$ |
|---|---|
| 50 Athletes Surveyed in Football | 70 ± 13 |
| 50 Athletes Surveyed in Soccer | 64 ± 10 |

a. State a null hypothesis for this experiment.

b. Use the space provided to make a bar graph comparing the sample means given in the table above. Make sure to plot the 95% CI (+/- 2SEM), using the values provided.




c. What conclusion can be drawn from this data? Circle the correct options below to complete the conclusion:

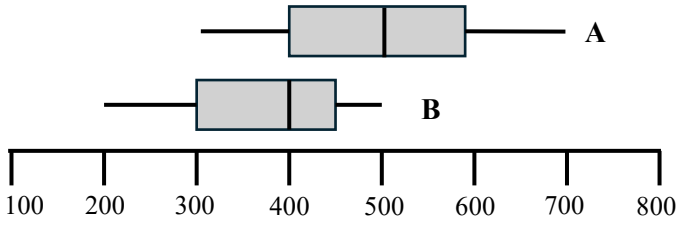
- There *is / is not* sufficient evidence to reject the null hypothesis. The athletic trainer's alternative hypothesis *is / is not* supported by the data. While the mean ounces of water consumed by football players is higher than the mean ounces of water consumed by soccer players, the error bars *overlap / do not overlap* indicating that the difference between the means *is / is not* significant.

3. You are comparing three data sets, each with the same standard deviation of 2.3. The only difference between the data sets is the sample size (n). Data set 1 has a sample size of 15, data set 2 has a sample size of 30, and data set 3 has a sample size of 45. Calculate the standard error for each data set.
   a. Data set 1:_____
   b. Data set 2:_____
   c. Data set 3:_____

4. Referring to question 3, what happened to the standard error when the sample size (n) was increased? Use the formula to justify why this happened.

5. What is the median of data set A? Data set B?

6. Which data set has more variability?

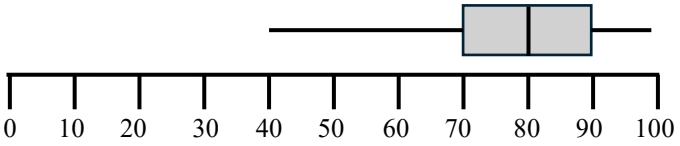



7. The diagram shows a box and whisker plot of student scores on their 9th grade biology test.

   a. What was the median score? _____

   b. What was the lowest score? _____

   c. What was the highest score? _____




   d. What percentage of students scored 70 or lower? _____

   e. What percentage of students scored 80 or lower? _____

8. Male lizards will do push ups to attract mates. A researcher counts the number of push ups done by a sample of eleven lizards throughout the course of one day: 300, 105, 400,521, 411, 500, 550, 52, 315, 75, 370. Using the data provided, identify the following:

   a. Minimum: _____

   b. $Q_1$: _____

   c. $Q_2$:_____

   d. $Q_3$:_____

   e. Maximum: _____

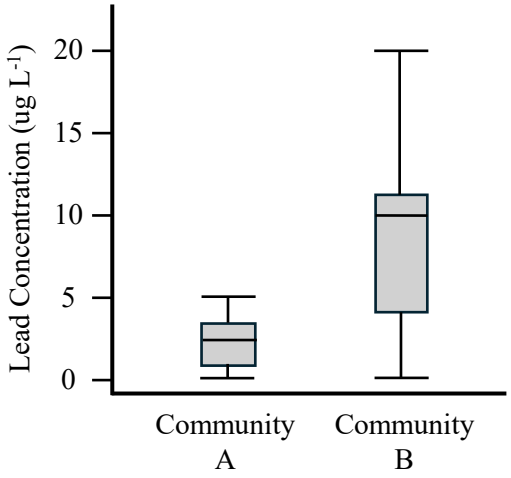
   f. What does IQR measure?

9. The box and whisker plot shows lead concentrations (ug $L^{-1}$) from rooftop-harvested rainwater. Samples were collected in two different communities to determine whether rainwater in different areas contains unsafe levels of lead.

   a. Which community has a lower median lead concentration?

   a. Which community has higher variability in lead concentration?

   a. Local health guidelines state that lead levels at or above 10ug/L-1 are unsafe. Is this value included within the IQR of either community? If so, what percent of the samples for that community were at or above this level?



10. A teacher is interested in the social media habits of her 9th grade vs 11th grade students. She hypothesizes that 9th grade students spend more time (in minutes) in a single day on social media apps than her 11th grade students.

A random sample of ten 11th grade students was taken. The data can be found below.

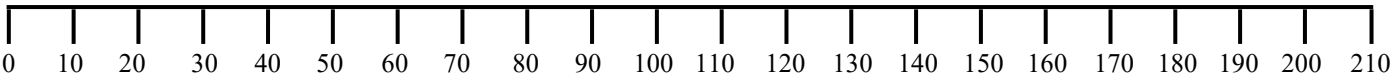
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 55 | 85 | 25 | 44 | 37 | 42 | 201 | 56 | 59 |

Let's work through this first one, step by step. Check off each box when you complete each step.

- ❑ Begin by arranging the numbers in increasing order.
- ❑ Find the median of the data set ($Q_2$). *Since there is an even number of values in this data set, take the average of the middle two values*.
- ❑ Mark $Q_2$ by drawing a vertical line between the middle two values. Label this line as $Q_2$ and write the median value calculated above it.
- ❑ Find the median of the lower half of the data set ($Q_1$). *Since $Q_2$ was calculated using the middle two values, $Q_2$ is a value that exists between the numbers provided. Therefore, when calculating $Q_1$, look at the values to the left of the $Q_2$ line. There should be 5 values.*
- ❑ Mark and label $Q_1$, by drawing a vertical line through the value.
- ❑ Find the median of the upper half of the data set ($Q_3$). *Since $Q_2$ was calculated using the middle two values, $Q_2$ is a value that exists between the numbers provided. Therefore, when calculating $Q_3$, look at the values to the right of the $Q_2$ line. There should be 5 values.*
- ❑ Mark and label $Q_3$, by drawing a vertical line through the value.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

Construct a box and whisker plot for the 11th grade data set using the number line below. (*We will add another box and whisker plot to this, so make sure there is enough space left*)



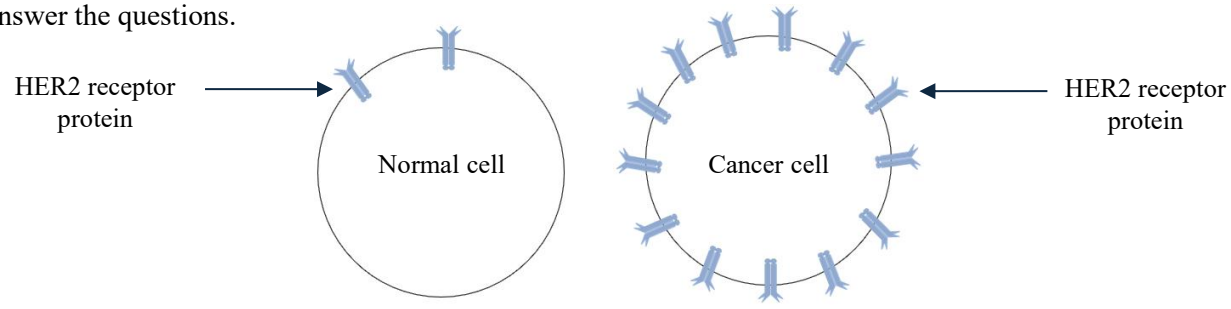

Data was also collected from a random sample of ten 9th grade students. Using the data below, construct a box and whisker plot for the 9th grade data set on the number line above.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 40 | 75 | 10 | 54 | 66 | 90 | 42 | 205 | 77 | 84 |

Examine the box and whisker plots. How do the median values and IQRs compare between the teacher's 9th and 11th grade students' social media usage?

## Statistics Practice Problems Part 2

A researcher has developed two new drugs: Herceptin and Perjeta. Both have shown promise in treating HER2-positive breast cancer. Approximately 10-20% of breast cancer cells test positive for a protein called HER2 on the surface of the cancer cell. This protein plays a pivotal role in the growth of the cancer cell. Cancer cells are cells that grow rapidly and do not follow the normal cell division pathway, thus forming tumors. Examine the image below and then answer the questions.




1. How does the cancer cell differ from the normal cell? What effect does this difference have?

2. In laboratory testing using a HER2-positive breast cancer cell line, the researcher has seen early success with the new treatments. In the lab, the researcher incubated the HER2-positive cell line in a petri dish. After the cells had time to grow, they were treated with a dose of Herceptin. The number of cancer cells that had undergone apoptosis, or cell death, was then examined to determine the effectiveness of the treatment. Examine the data collected below, then calculate the mean. Go to the next page and add the mean that you calculated as a bar to the graph. (**note: we will be adding more to the graph as you progress through the questions*).

| Herceptin Alone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trial: | 1 | 2 | 3 | 4 | 5 | Mean | STDEV | +/-2SEM |
| % Apoptotic Cells | 20.35 | 22.5 | 11.7 | 15 | 20.45 | | 4.49 | |

3. Next, the researcher tested Perjeta. The researcher repeated the same process as above, except this time the researcher treated the cells with Perjeta. Examine the data collected below, then calculate the mean and add that as a bar to the graph on the next page.

| Perjeta Alone | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trial: | 1 | 2 | 3 | 4 | 5 | Mean | STDEV | +/-2SEM |
| % Apoptotic Cells | 25 | 22.5 | 19.5 | 25 | 23 | | 2.26 | |

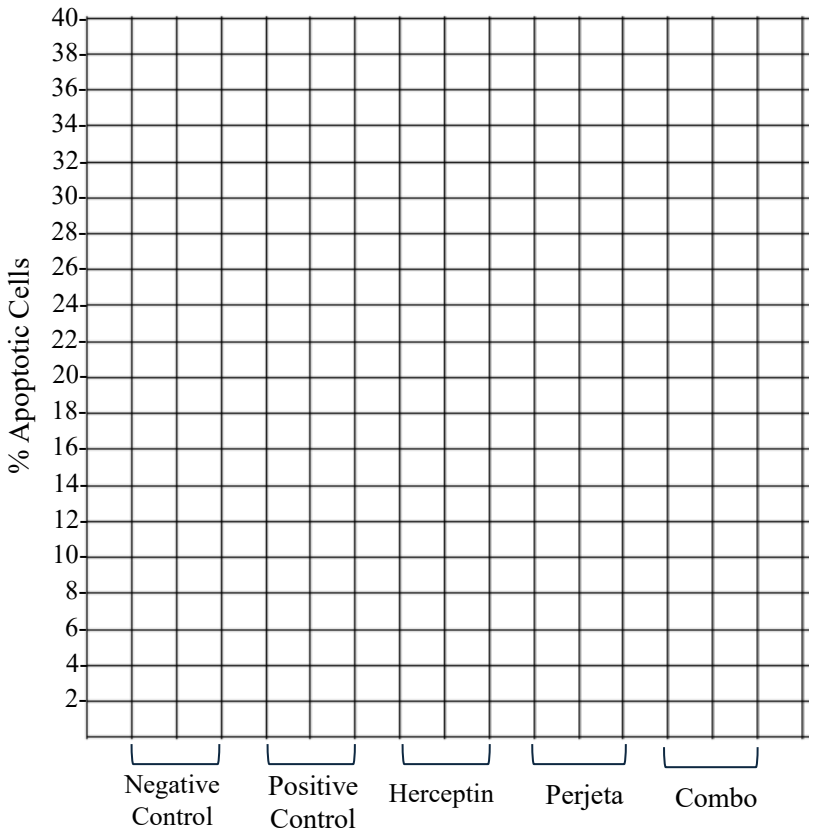
4. Look at the bars you added for the mean % apoptosis of cancer cells treated with Herceptin and Perjeta. How would you interpret this data?

5. Finally, the researcher tested a combination treatment (Herceptin + Perjeta), repeating the same process as before. Examine the data collected below, then calculate the mean and add that as a bar to the graph.

| Combination (Herceptin and Perjeta) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Trial: | 1 | 2 | 3 | 4 | 5 | Mean | STDEV | +/-2SEM |
| % Apoptotic Cells | 31.7 | 31 | 29.3 | 32 | 31 | | 1.05 | |

6. How does the mean % of apoptotic cancer cells in the combination treatment group compare to the mean values for those treated with only Herceptin and Perjeta?

Efficacy of New Breast Cancer Drugs




7. Go back to questions 2, 3, and 5. For each, calculate the 95% confidence intervals for the data sets. *Hint*: *to do this, first find the standard error of the mean (SEM), then multiply the SEM by 2 to estimate the 95% confidence interval.*
8. Why is the SEM so much higher for the Herceptin group versus the Perjeta group?

9. Add the respective 95% confidence intervals (mean +/- 2 SEM) to the Herceptin, Perjeta, and combination treatment bars.
    a. Did adding the error bars (95% CI) change your interpretation to question 4, whether Herceptin and Perjeta are significantly different in terms of their ability to cause apoptosis in the cancer cells? Why or why not?

    b. Did adding error bars (95% CI) change your interpretation to question 6, whether the combination treatment is significantly different from either individual treatment at causing apoptosis in the cancer cells? Why or why not?

10. The researcher performed the same experimental set-up with both positive and negative control groups (simultaneous to the experimental groups). For the negative control, the researcher incubated HER2-positive cancer cells in a petri dish with no treatment and then recorded the number of cells that had undergone apoptosis. For the positive control, the researcher used a radiation treatment known to be successful in killing HER2-positive cancer cells. This treatment, however, has many negative side effects when used on patients, which is why finding an alternative treatment is necessary. The researcher incubated the HER2-positive cells, then exposed them to radiation and then recorded the number of cells that had undergone apoptosis. Examine the data collected below and then calculate the mean and the 95% confidence interval. Add the means and 95% confidence intervals to the graph.

| Trial: | 1 | 2 | 3 | 4 | 5 | Mean | STDEV | +/-2 SEM |
|---|---|---|---|---|---|---|---|---|
| % Apoptotic Cells in Negative Control | 3 | 5 | 5 | 5 | 5 | | 0.89 | |
| % Apoptotic Cells in Positive Control | 30.5 | 33.5 | 40 | 36 | 35 | | 3.48 | |

11. Let's compare the treatments to the positive control.
    a. Compare the effects of Herceptin and Perjeta to the positive control (radiation). For both Herceptin and Perjeta, identify whether it is more effective, as effective, or less effective than the positive control. Justify your response with evidence from the data.

    b. Compare the effect of the combination treatment to the positive control (radiation). Identify whether the combination treatment is more effective, as effective, or less effective than the positive control. Justify your response with evidence from the data.

12. What would it mean if the negative control had overlapping error bars with the treatments?

13. Based on the results, which treatment would you recommend be studied further? Why?

## Topic 1: Structure of Water and Hydrogen Bonding

**Chemistry Review**

| Matter | Element | Compound |
|---|---|---|
| Anything that takes up _____ and has _____.<br>• Rocks, metals, oils, gases, organisms, etc. are all forms of matter | A substance that _____ be broken down into other substances by chemical reactions<br>• 92 elements occur in nature<br>• Periodic table | A substance consisting of _____ or more different _____ combined in a fixed ratio<br>• $H_2O$<br>• NaCl |

Essential elements: of the 92 naturally occurring elements 20-25% are essential to _____ and _____. CHOPN make up 96% of living matter

Trace elements: of the 92 naturally occurring elements, these are required by an organism in very _____ quantities

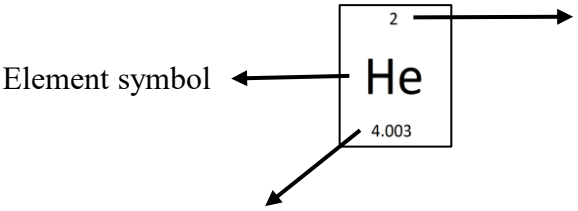
**Research, Pair, Share**

Search up the essential elements. Why are they essential? (i.e. what major roles do these elements play in the human body?

Search up trace elements. What are a few examples of trace elements and their purpose in the human body?

➔Questions?
➔Textbook chapters/pages to review

**Chemistry Review**

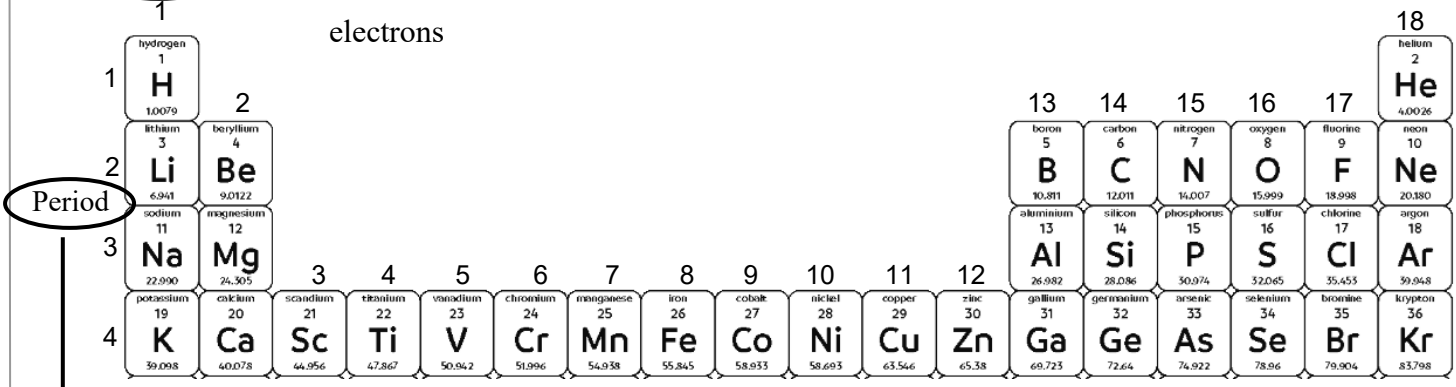



Element symbol

Atomic number: number of _____

Atomic mass: number of _____ plus _____ averaged over all isotopes

Group → Elements in the same _____ column have the same number of _____ electrons




Elements in the same _____ row have the same total number of _____ shells

*Think, Pair, Share*

What else do you remember about the periodic table?

➔Questions?
➔Textbook chapters/pages to review

**Types of Bonds**

Elements want to be _____

- Achieve this by forming chemical _____ with other elements
- **Octet rule**: elements will gain, lose, or share electrons to complete their _____ shell and become _____ (like noble gases)

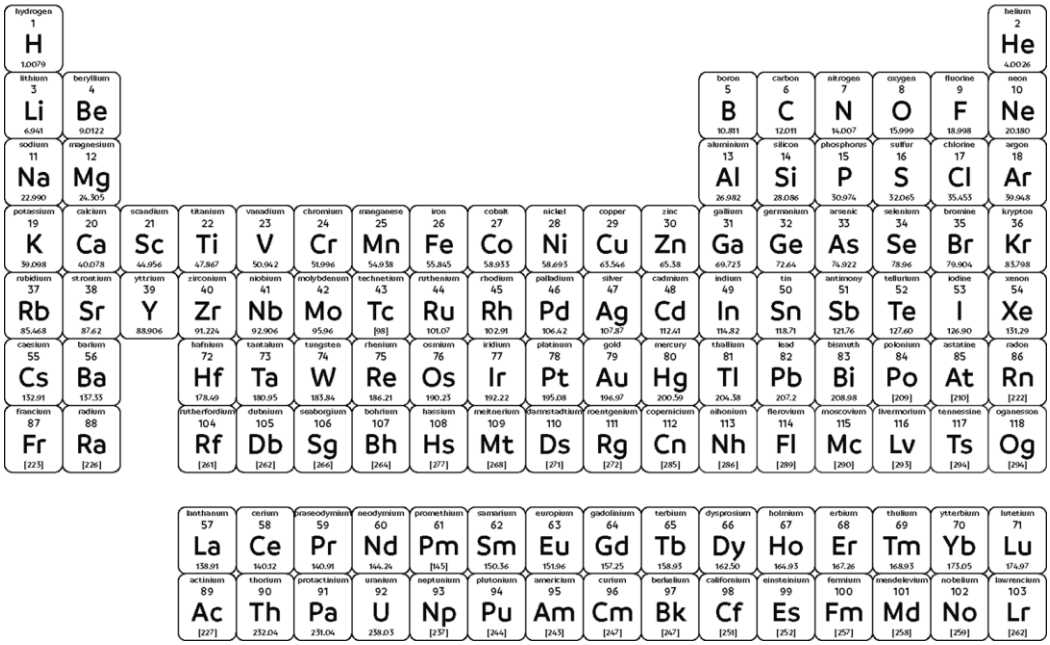
  - Valence shell: outermost layer of electrons in an atom

**Chemical Bonds**: an attraction between two atoms, resulting from the _____ or _____of valence electrons

**Electronegativity**: the measure of an atom's ability to _____ electrons to itself

Electronegativity _____ →

Electronegativity _____ ↓






➔Questions?
➔Textbook chapters/pages to review

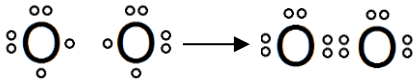
**Covalent bonds**: when two or more atoms _____ electrons (usually between two nonmetals)

- Forms molecules and compounds
  - Single bond: ___ pair of shared e-
  - Double bond: ___ pairs of shared e-
  - Triple bond: ___ pairs of shared e-

- There are two types of covalent bonds: _____ covalent and _____ covalent

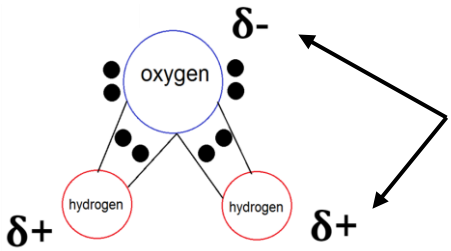
**Nonpolar covalent:** electrons are shared _____ between two atoms

- Example: $O_2$



**Polar covalent:** electrons are _____ shared equally between two atoms

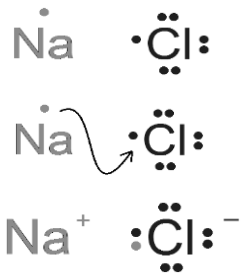
- Example: $H_2O$




Unequal sharing of e- results in _____ charges on oxygen and hydrogen

**Ionic bonds**: the attraction between _____ charged atoms (_____)

- Usually between a _____ and _____ (_____ transfers electrons to _____)
- Forms _____ compounds and _____
  - NaCl
  - LiF
- Occurs when there is a _____ of electrons from one atom to another atom forming _____
  - Cation: _____ charged ion
  - Anion: _____ charged ion




➔Questions?
➔Textbook chapters/pages to review

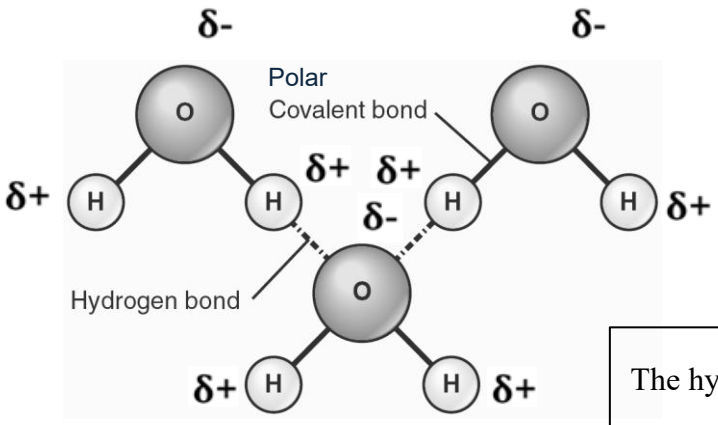
**Hydrogen bonds**: the partially positive hydrogen atom in _____ polar covalent molecule will be _____ to an electronegative atom in _____ polar covalent molecule

- Intermolecular bond: bond that forms _____ molecules

*Why does this happen?*

- When a hydrogen atom is bonded to an electronegative atom (usually O, N, or F) the electrons are _____being shared _____ between atoms (remember this is a **polar covalent bond**)
    - This causes the hydrogen to have a **partial _____ charge** and the electronegative atom to have a **partial _____ charge**

o Example: _____bonds between _____ molecules

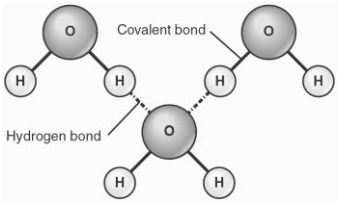



The hydrogen bonds between water make it more structured than most liquids

Water molecules move a lot! Hydrogen bonds form, break, and re-form with great frequency

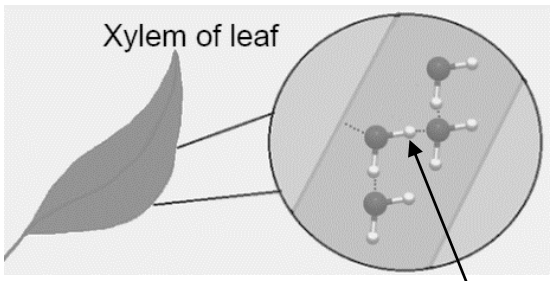
➔Questions?
➔Textbook chapters/pages to review

**Properties of water**



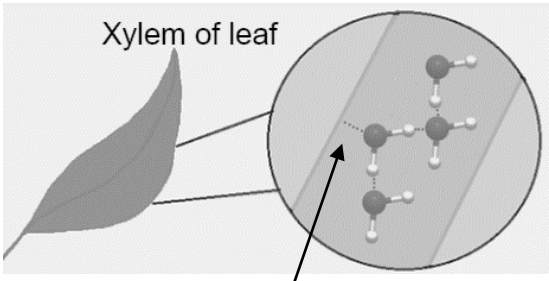

1. Polarity: _____ _____bonds created by unequal sharing of electrons between oxygen and hydrogen _____ the molecule of water

2. Cohesion: _____of molecules for other molecules of the _____ kind ($H_2O$ to $H_2O$)
   - _____ bonds between $H_2O$ molecules hold them together and _____ cohesive forces
   - Allows for the transport of water and nutrients _____ _____ in plants
   - Responsible for _____ _____
     - Surface $H_2O$ molecules experience greater _____ pull because there are no molecules above them to balance the forces

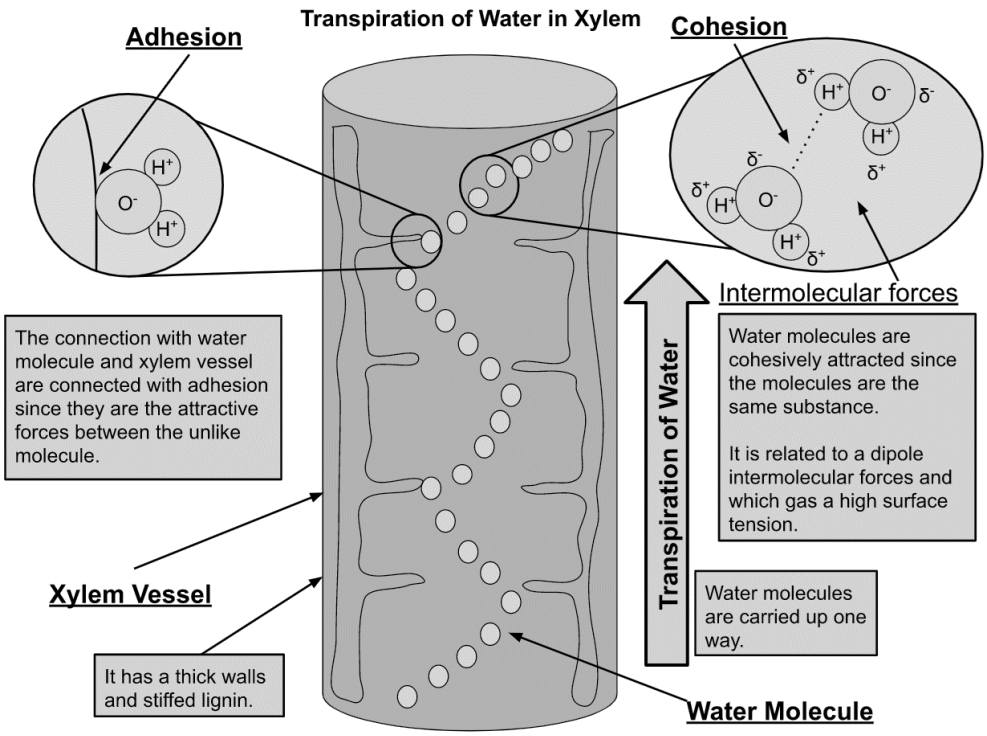



Cohesion: $H_2O$ molecules stick together

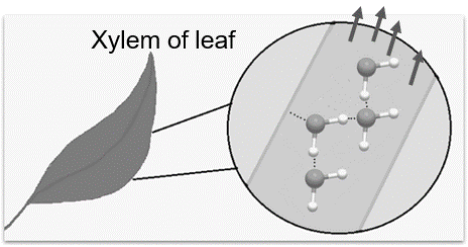
3. Adhesion: the attraction to _____ molecules that are _____ or have charge ($H_2O$ to other molecules)
   - Due to the _____ of $H_2O$
     - In plants, this allows water to cling to the _____ walls to resist the downward pull of gravity




Adhesion: $H_2O$ molecules stick to the xylem wall

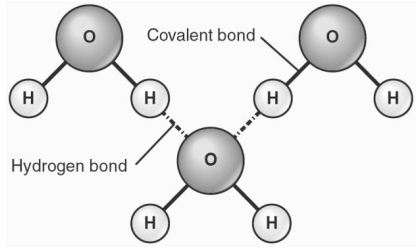


4. Capillary action: the _____ movement of water due to the forces of cohesion, adhesion, and surface tension
   - Occurs when _____ is **greater than** _____
     - Important for transport of water and nutrients in plants

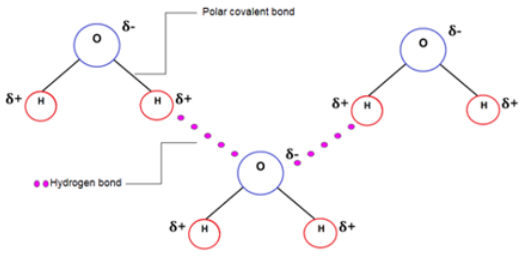



Capillary action occurs moving water upwards

5. Temperature Control
   - ➢ High specific heat: $H_2O$ resists _____ in temperature
     - How? _____ _____
       - Heat must be _____ to break hydrogen bonds, but heat is _____ when hydrogen bonds form
     - Importance of high specific heat:
       - *Moderates air temperature*
         - Large bodies of water can _____ heat in the daytime and _____ heat at night
       - *Stabilizes ocean temperature*
         - Benefits marine life
       - *Organisms can _____ changes in their own internal temperature*
   - ➢ High heat of vaporization: water requires a large amount of _____ to evaporate due to strong hydrogen bonds
     - Evaporative cooling: as water molecules evaporate, the surface they evaporate from gets _____
       - Importance of evaporative cooling:
         - Moderates Earth's _____
         - Stabilizes _____ in lakes and ponds
         - Prevents terrestrial organisms from _____ (think sweating in humans)
         - Prevents leaves from becoming too _____ in the sun



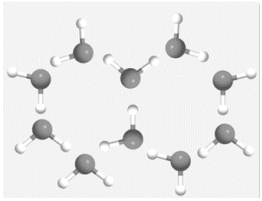

Tempersture control properties of $H_2O$ stem from these hydrogen bonds




➔Questions?
➔Textbook chapters/pages to review

6. Density (floating ice): as water solidifies it _____ and becomes less _____
   - Due to the _____ bonds
   - When cooled, $H_2O$ molecules move too _____ to _____ the bonds
     - Allows marine life to survive under floating ice sheets

Hydrogen bonds cause water molecules to form a _____ structure



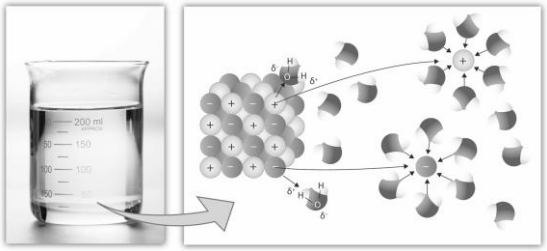
Think, Pair, Share

Imagine the 3D crystalline structure of ice. How many hydrogen bonds can one molecule of water make with its neighboring water molecules?

7. Solvent: _____ agent in a solution
   - Water is a versatile solvent
     - Its polar molecules are attracted to ions and other polar molecules it can form _____ bonds with
   - *Solution*: homogenous mix of _____ substances
   - *Solvent*: dissolving agent in a solution
   - *Solute*: _____ that is dissolved

Remember: "_____ dissolves _____"

- Water can interact with sugars or proteins containing many oxygen and hydrogen
- Water will form _____ bonds with the sugar or protein to _____ it
- Ionic compounds
  - The partially _____ oxygen in water will interact with a _____ atom
  - The partially positive hydrogen in water will interact with a negative atom
  - _____ ions



➔Questions?
➔Textbook chapters/pages to review

8. pH and buffering

- pH a measure of how _____ or _____ (alkaline) a solution is
    - Acid: substance that releases _____ ions (H+) when dissolved in water
    - Base: a substance that accepts H+ OR releases _____ ions (OH-)
    - ➢ Water can dissociate into hydrogen (H+) and hydroxide ions (OH-)
- Buffer: a solution that resists _____ in pH when an acid or base is added
    - ➢ Buffers help maintain pH stability in biological systems

**Concept Check**

1. Predict what would happen if you mixed potassium chloride (KCl) with water. *Optional: draw and label a diagram to justify your explanation.*

2. Identify one property of water that contributes to the suitability of the environment for marine life.

3. Predict one disruption that would occur in the environment if ice was MORE dense than water.

➔Use this space to reflect on topic 1
➔Textbook chapters/pages to review

**Properties of Water: Stations Lab**

**Directions**: This lab station activity is designed to help reinforce your understanding of the properties of water. Complete the activities and questions provided at each station.

**Station 1: Polarity**

*Follow the directions to complete the station then complete the questions below.*

1. What causes polarity in water?

2. Draw a water molecule and label the partial charges.

3. Prior to rubbing the plastic with the cloth, both the rod and cloth had a neutral charge. After rubbing them together, what was the net charge of the rod? Of the cloth?

4. What caused the phenomenon observed in step 5?

5. Draw how water molecules (in the stream of water) would have been oriented towards the rod in step 5. Justify your drawing with an explanation and link it to the concept of polarity.

6. Was the phenomenon observed in step 8 different from the one observed in step 5?

7. If the phenomenon in step 8 was different from step 5, hypothesize why.

**Station 2: Surface Tension**

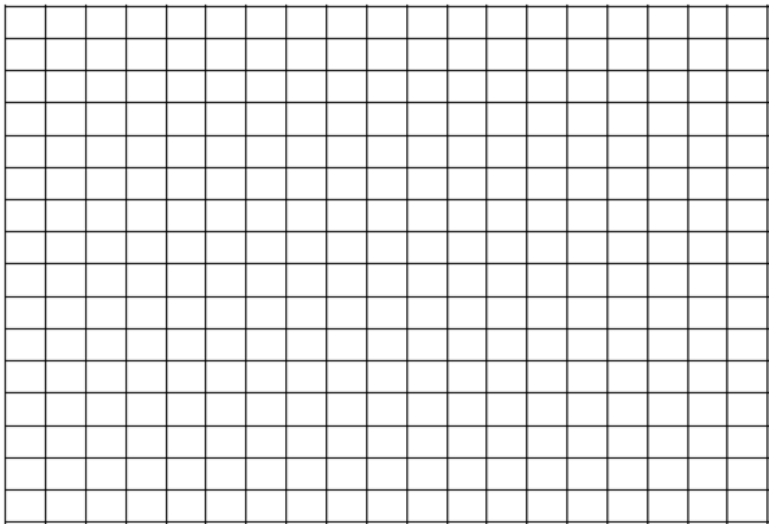
*Follow the directions to complete the station then complete the questions below.*

1. Fill in the data obtained in the chart below:

| | Trial 1 | Trial 2 | Trial 3 | Average |
|---|---|---|---|---|
| Water only | | | | |
| Water and soap | | | | |

2. Calculate the standard deviation (in excel/calculator) and standard error below:

3. Create a graph based on your data, including 95% confidence intervals (*make sure the graph is labelled appropriately*).



4. How did the addition of soap affect the surface tension of the water? Hypothesize why this happened.

**Station 3: Adhesion vs Cohesion**

*Follow the directions to complete the station then complete the questions below.*

1. Create a Venn diagram to compare and contrast adhesion and cohesion.

2. What allows for both adhesion and cohesion?

3. Using Figure 1 on the station paper, identify 1, 2, and 3 with the process being depicted.

4. Looking at Figure 2 on the station paper, how do the water molecules on the top layer differ from the water molecules in the middle layer.

5. In reference to question 4, what does this create on the surface of the water?

6. How are cohesion, adhesion, and surface tension important in nature?

**Station 4: Capillary Action**

*Follow the directions to complete the station then complete the questions below.*

1. Hypothesize what you expect the levels of water to be in each straw.

2. How do your results compare to what you hypothesized?

3. What causes capillary action?

4. Look at Figure 1 showing the results of a capillary tube being placed in a beaker of water and in a beaker of mercury. Which meniscus is convex? Which meniscus is concave?

5. Referring to Figure 1, notice that water shows capillary attraction, while mercury shows capillary repulsion. Using your knowledge of capillary action, propose a reason why the meniscus of mercury appears different than that of water.

**Station 5: Solvent**

*Follow the directions to complete the station then complete the questions below.*

1. Why is water considered a “universal solvent?”

2. How is water able to dissolve other substances?

3. What is the purpose of our kidneys?

4. How do the circulatory and urinary systems work together?

5. How does water play a role in kidney function?

6. What are the effects of long term dehydration on the kidneys?

**Station 6: Temperature Control and Density**

*Follow the directions to complete the station then complete the questions below.*

Data:

| | Temp of Water with no Foil | Temp of Water with Foil |
|---|---|---|
| 10 min | | |
| 20 min | | |
| 30 min | | |

1. After reading the article, what is the foil in the bin supposed to represent?

2. How did the temperature of water in the bin with no foil compare to that of the bin with the foil?

3. Why does ice float? Draw a diagram of liquid water vs solid water to justify your reasoning.

4. What is sea ice?

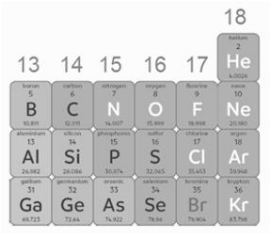
5. How does sea ice benefit marine life? (*link to the temperature control properties of water*)

6. How does sea ice affect the global climate?

7. Did the results of the experiment support the information you read? If not, propose a reason why.

## Topic 2: Elements of Life

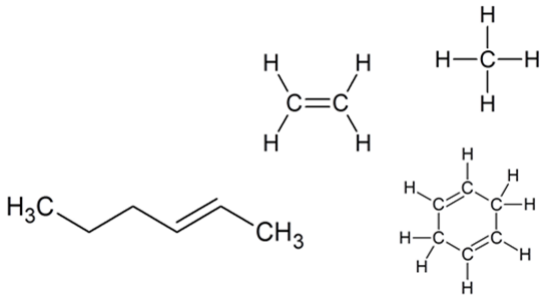
### Carbon




**Organic chemistry**: the study of compounds with covalently bonded _____

**Organic compounds**: compounds that contain _____ and _____

- Carbon has _____ valence electrons
- Carbon can form _____, _____, or _____ covalent bonds
    - A single carbon can form up to _____ covalent bonds!
    - Can form LONG chains
- Most commonly formed with _____, _____, and _____
    - The type and number of covalent bonds carbon forms with other atoms affects the _____ of the carbon chain and _____ of the molecule

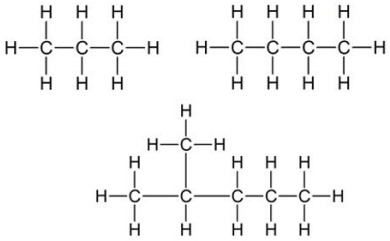



### Carbon Chains

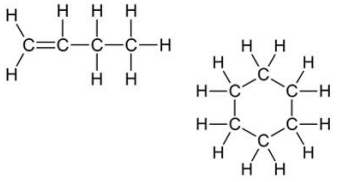
Carbon can use its _____ electrons to form _____ bonds to other carbons

- This links the carbons into a _____
- Hydrocarbons- organic molecules consisting only of _____ and _____ (think: simple framework for more complex organic molecules)

Carbon chains form the _____ of most organic molecules



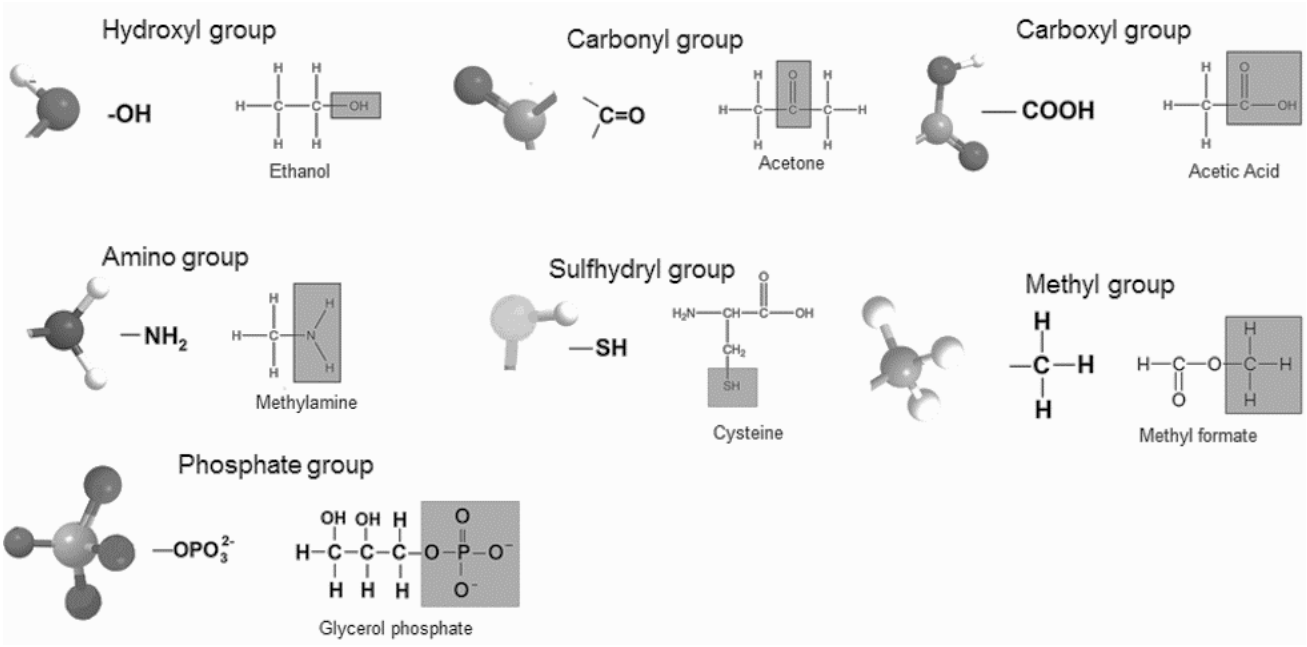
- Skeletons can vary in:
    - Length
    - Branching
    - Double bond position
    - Presence of rings
- Many regions of a cell's organic molecules contain _____



➔Questions?
➔Textbook chapters/pages to review

Functional groups: _____ groups attached to the carbon skeleton that participate in chemical

_____




➔Use this space to reflect on topic 2

➔Textbook chapters/pages to review

## Topic 3: Introduction to Macromolecules

### Molecular Diversity Due to Carbon

- Variations in carbon skeletons allows for _____ _____
- Carbon can form large molecules known as _____
- Four classes of macromolecules (molecules made of smaller subunits):

1. Carbohydrates
2. Proteins
3. Nucleic acids
4. Lipids

_____

NOTE: Along with carbon, _____ is an important element for building <u>proteins</u> and <u>nucleic acids</u>. _____ is important for building <u>nucleic acids</u> and some <u>lipids</u>. _____ is used in the building of proteins

- Does not include true polymers and are _____ molecules

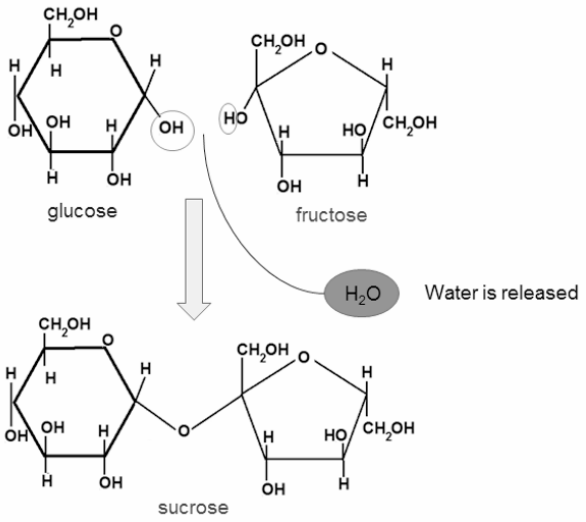
### Formation and Breakdown of Macromolecules

**Polymers**: chain like macromolecules of _____ or _____ repeating units that are covalently bonded together

**Monomers**: the repeating units that make up _____

**Dehydration reaction**: _____ bonds two monomers with the _____ of _____

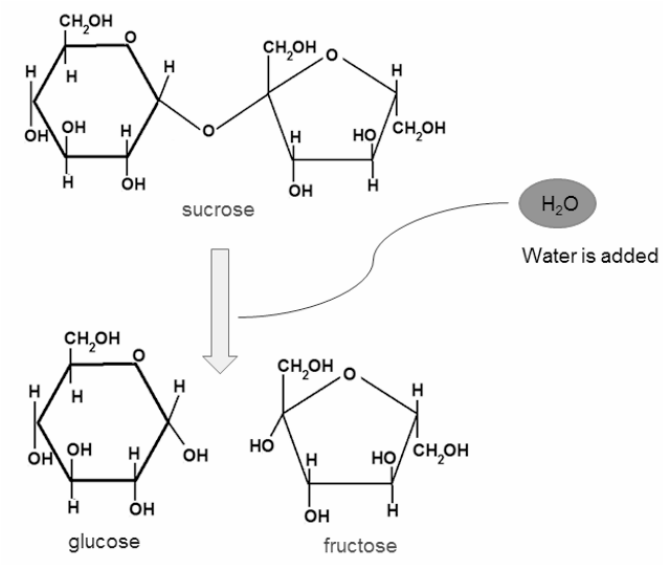
- The _____ of one monomer bonds to the ____ of another monomer forming _____, which is then released
  - A+B→AB + H2O
- Polymerization: the connection of _____ monomers




➔Questions?
➔Textbook chapters/pages to review

**Hydrolysis**: _____ the covalent bonds in a polymer by adding _____

- One ____ of the $H_2O$ bonds to one _____ and the remaining _____ of the $H_2O$ attaches to the other _____
  - AB + H2O → A+B



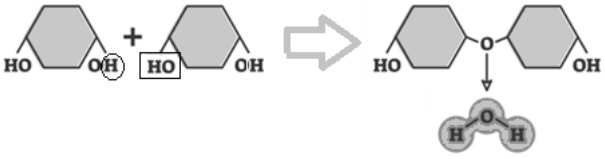

**Concept Check**

1. You are performing an experiment that involves a hydrolysis reaction. The polymer that you are working with is amylose starch. There are 300 monomers of glucose that make up this polymer. How many water molecules will you need to completely hydrolyze the amylose starch polymer?

2. Describe the properties of carbon that make it an element essential for life.

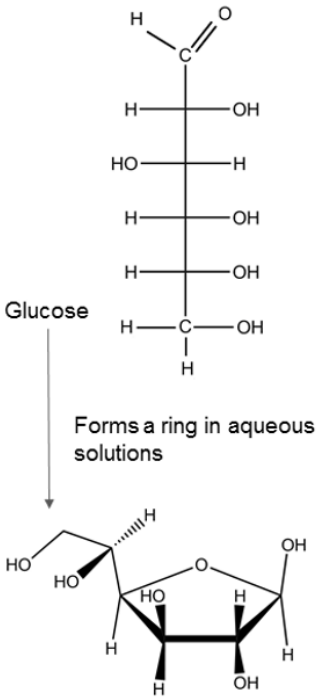
3. Look at the periodic table and find silicon. What do you notice about its position in comparison to carbon? What does that tell us about silicon?

4. Identify whether the image below shows a dehydration reaction or hydrolysis reaction. Why?



➔Use this space to reflect on topic 3
➔Textbook chapters/pages to review

## Carbohydrates




- Includes _____ and _____ of sugars
- Contain a _____ group and many_____ groups
    - Comprised of C, H, and O

**Monosaccharides**: simple _____

- Molecular formulas with multiples of the unit _____
- Most common is _____
    - Nutrients and _____ for cells
    - Used in _____ _____
- Can serve as building blocks for _____ acids, or as _____ for di- and polysaccharides

**Disaccharides**: _____ monosaccharides joined together by covalent bonds

- Most common is _____
    - Monomers of sucrose: _____ and _____
    - Plants transfer carbohydrates from roots to leaves in the form of sucrose

**Polysaccharides**: polymer with _____ sugars joined via _____ reactions

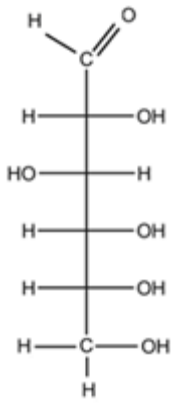
- Storage polysaccharides
    - Plants store _____ (polymer of glucose monomers)
        - Allows plants to store excess _____
    - Animals store _____ (polymer of glucose)
        - Stored in liver and muscle cells
- Structural polysaccharides
    - _____: tough substance that forms plant cell walls
    - _____: forms exoskeleton of arthropods

### Practice

1. You are given an unknown monosaccharide to identify in the lab. The only clue you are given is that it has 4 carbons. You (being an excellent AP Bio student) figure out the formula and name immediately. What is the unknown monosaccharide?

➔Questions?
➔Textbook chapters/pages to review

## Practice Problems: Carbohydrates

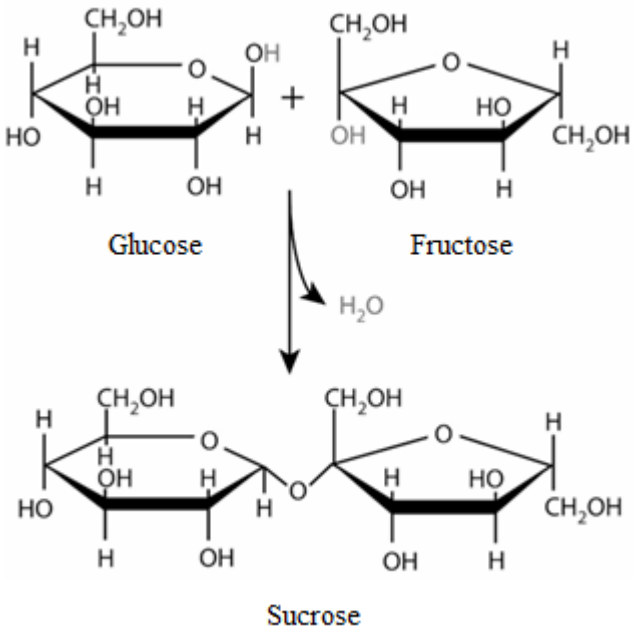


Glucose

1. What elements make up carbohydrates?

2. What are the monomers of carbohydrates? What are the polymers?

3. What two functional groups make up carbohydrates? Identify them on the image to the right.




*Use the diagram to the left to answer questions 4-7.*

4. What monosaccharides are involved in the reaction?

5. What forms when two monosaccharides are covalently bonded together?

6. Identify and describe the reaction that takes place between glucose and fructose to form sucrose.

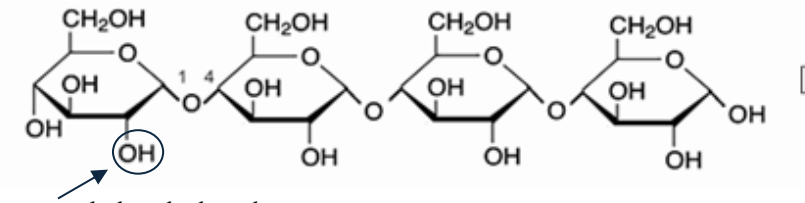
7. Identify and describe the reaction that would need to take place to break sucrose apart back to glucose and fructose.

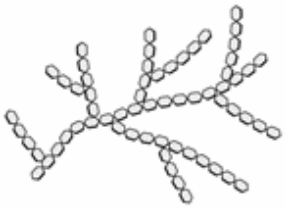
8. Glucose is important for both plants and animals, but the way that plants and animals store glucose differs. Identify the polysaccharides that plants and animals use to store excess glucose

➔Questions?
➔Textbook chapters/pages to review

Cellulose is a major component of the tough cell walls in plant cells. It is formed from glucose monomers and has 1-4 glycosidic linkages. A glycosidic linkage is a type of covalent bond that joins a carbohydrate (sugar) molecule to another carbohydrate. The **1,4** glycosidic bond is formed between the carbon-**1** of one monosaccharide and carbon-**4** of the other monosaccharide. Similar to cellulose, starch is also comprised of 1-4 glycosidic linkages between glucose monomers. If this is true, then how are starch and cellulose structurally different? Examine the image below to answer questions 9-10.

Starch

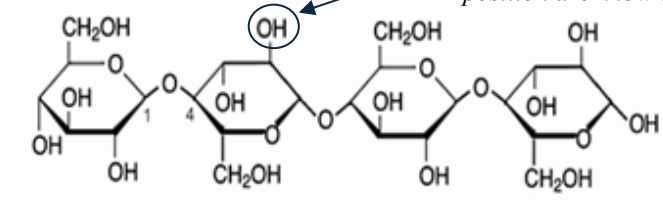


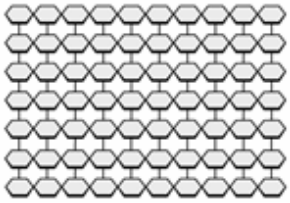


*Glucose monomers with their hydroxyl group in this position are known as alpha glucose monomers*

*Glucose monomers with their hydroxyl group in this position are known as beta glucose monomers*

Cellulose





9. What structural differences can be found between starch and cellulose?

10. Explain and justify how the structural differences between starch and cellulose lead to functional differences in plants.

11. Some nutritional labels for plant-based food may include an "insoluble fiber" category. Insoluble fiber is in reference to cellulose and is also called "roughage." Cellulose is considered insoluble because humans cannot digest it. However, cellulose is still recommended to be consumed as a part of a healthy diet. Why might this be? *To answer this question research insoluble fiber on your own and record your findings here before formulating a well written response.*

| | |
|---|---|
| Dietary Fiber 5g | 18% |
| Soluble Fiber 2g | |
| Insoluble Fiber 3g | |

➔Questions?
➔Textbook chapters/pages to review

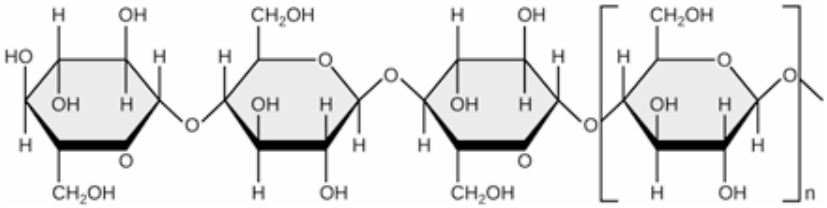
## Case Study: Cellulose

### Background

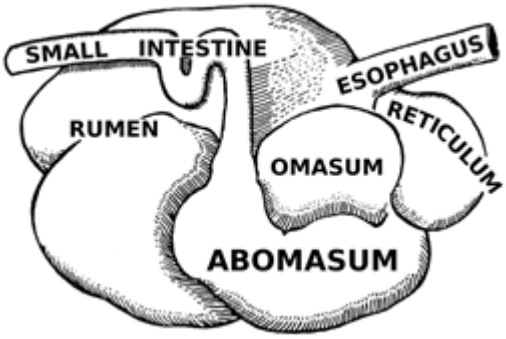
Cellulose is a complex carbohydrate consisting of thousands of glucose monomers connected by 1-4 glycosidic linkages. These long strands of glucose monomers organize side by side and stay connected through hydrogen bonds. These hydrogen bonds stabilize the long strands into tight bundles that are organized into fibers

Cellulose fibers

Cellulose structure



Cellulose is an extremely important component of plants, as it makes up the tough cell walls present in plant cells. Humans are unable to digest cellulose, as enzymes in the stomach cannot break the bonds between the glucose monomers. Cows, horses, goats, sheep, and termites are among the few organisms with unique digestive systems that are capable of cellulose digestion.




### Anatomy of a Cow's Stomach

Have you ever heard that cows have four stomachs? While this is not technically accurate, a cow's digestive system is highly evolved to digest the tough food it consumes. Cows have what is called a ruminant stomach. Ruminant stomachs are massive organs that have four separate chambers to digest food. Each chamber is so unique that some people refer to each chamber as its own stomach. The four compartments include: the rumen, the reticulum, the omasum, and the abomasum.

The rumen is the largest compartment of the stomach and can hold up to 25 gallons of material to be digested! All animals have bacteria in their digestive tract, but bacteria found in the rumen are unique to animals like cows, horses, goats, sheep, and termites that can digest cellulose. Inside the rumen are billions of bacteria that begin digestion of plant material through fermentation.

Have you ever noticed that when you look at a cow it always seems to be chewing something? Well, it is! The rumen will contract to push up partially digested balls of food, called "cud." The cow will chew the cud a second time before it returns to the rumen for further digestion via bacterial fermentation. Cud chewing is also used as a health indicator in cattle. The second compartment of the stomach is the reticulum, which is a pouch like structure. Dense, heavy, and hard food objects are processed through the reticulum.

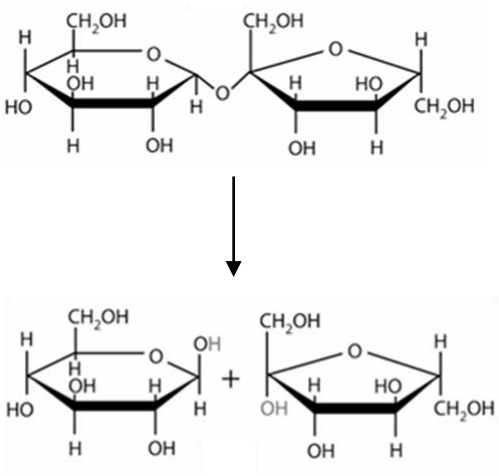
The third compartment of the stomach is the omasum, which is where water and nutrients are absorbed. When the food leaves the omasum, it is denser and drier. The abomasum is the last compartment of the stomach. The abomasum contains glands that release acid to break down the food in a similar way to human stomachs.

**Analysis**

1. Humans are unable to digest cellulose. No animal, in fact, can digest cellulose with their OWN digestive enzymes. Knowing this, predict what you think is actually responsible for digesting cellulose in a cow's stomach. Why?

2. Propose a model for how what you identified in question 1 is able to break down cellulose (i.e. what bonds are broken, what type of reaction is taking place).

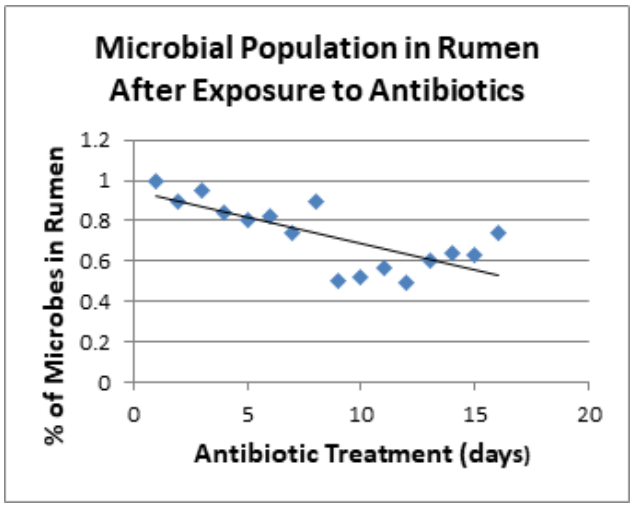
3. Add the missing component to the diagram below to show the input needed for this reaction to occur.



4. Cattle industries will often add antibiotics in their feed. What is the purpose of antibiotics? Why might cattle industries use them? *You may use online resources to research this.*

**Analysis**

5. Examine the chart. What happens to the rumen microbial population after cattle are given antibiotics? How might this affect their digestion?




6. Discuss the pros and cons to antibiotic use in cattle.

7. Do you think that antibiotics should be used in in farming? Justify your response. *You may use online resources to research this.*

**Lipids**

Lipids: class of molecules that do ____ include _____ polymers

- Generally _____ in size
    - Often not considered to be a macromolecule
- Lipids are nonpolar- _____

*Types of lipids:*

1. Fats
2. Phospholipids
3. Steroids
4. Cholesterol

***Fats***

Major Functions:

- Provide _____ storage
- Support _____ function
- Provide _____ to keep mammals warm

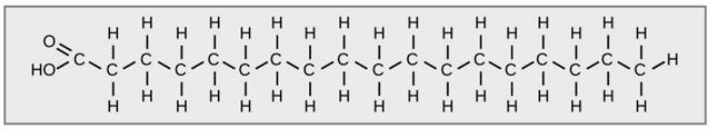
Fats are composed of _____ and _____ _____

- Glycerol: classified as an _____ (_____ groups)
- Fatty acids: long carbon chains (_____ group at one end)
    - 3 fatty acids join to a glycerol via _____ _____
        - Bond between a _____ and _____ group
    - Classified as a _____ **fatty acid** or an _____ **fatty acid**
        - Saturated fatty acid: _____ _____between carbons in the carbon chain = more _____ (think: saturated with hydrogen)
        - Unsaturated fatty acid: contains one or <u>more</u> _____ bonds
            - The double bonds cause the fatty tails to form _____
            - The more double bonds, the more _____ it is at room temperature

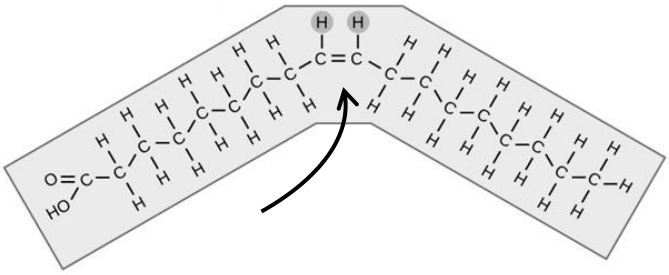


➔Questions?
➔Textbook chapters/pages to review

**Saturated fatty acid**



**Unsaturated fatty acid**



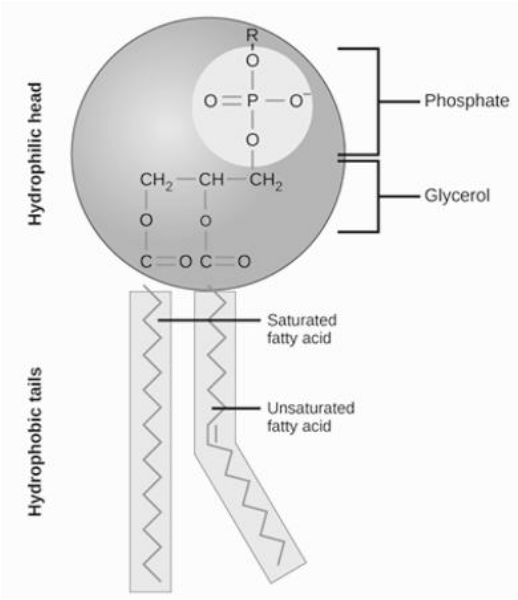
***Phospholipids***

Major component of cell _____

- Two fatty acids attached to a _____ and a _____

Assemble as a bilayer in $H_2O$

- Tails are _____
- Head is _____




***Steroids***

Steroids: _____ that support physiological functions like _____ and development, _____ metabolism, and _____

- Have four fused rings
    - Unique _____ attached to the ring determine the type of steroid
        - Example: testosterone

***Cholesterol***

Provides structural _____ to animal _____ membranes (*will go into more detail in unit 2*)

➔Questions?
➔Textbook chapters/pages to review

**Nucleic acids**

Nucleic acids: polymers made of _____ monomers

Function to:

- Store, transmit and express _____ information
- Two forms:
  1.
  2.

**Components of nucleic acids**

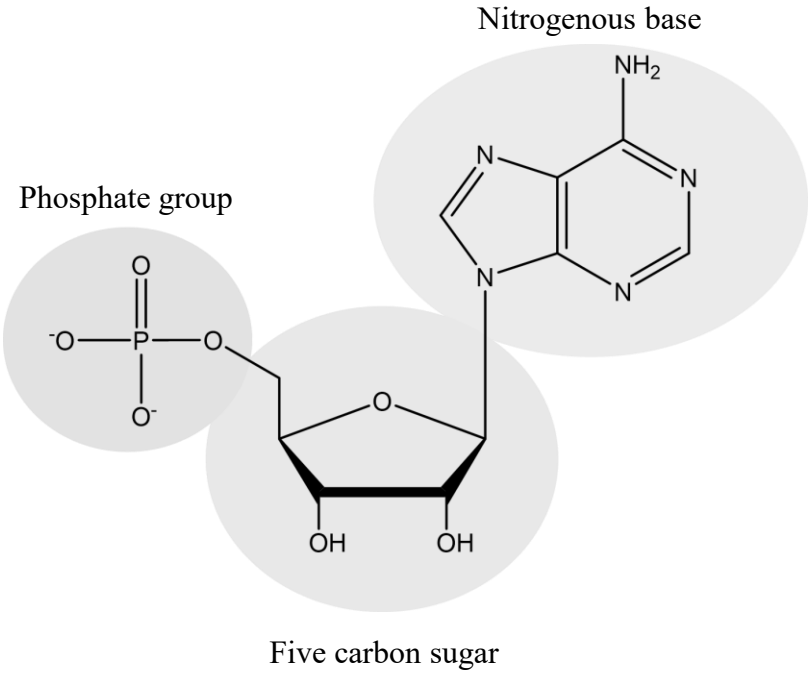
Nucleotides → Polynucleotides → Nucleic acids

***Nucleotides***

Contain 3 parts:

1. _____ base
2. Five carbon _____ (pentose)
3. _____ group(s)

In polynucleotides each monomer only has _____ phosphate group

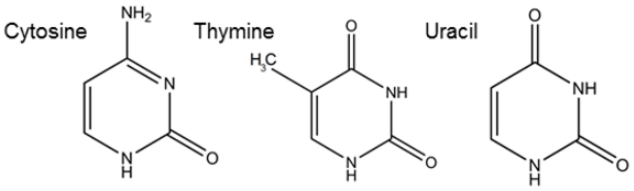



➔Questions?
➔Textbook chapters/pages to review

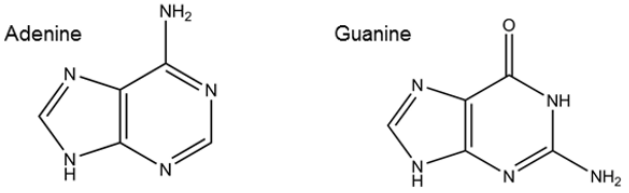
*Nitrogenous Base*

Two types: _____ and _____

- Pyrimidines: ____ ring with ___ atoms
  - Cytosine
  - Thymine
  - Uracil




- Purines: _____ ring with ___ atoms bonded to ____ ring with ___ atoms
  - Adenine
  - Guanine

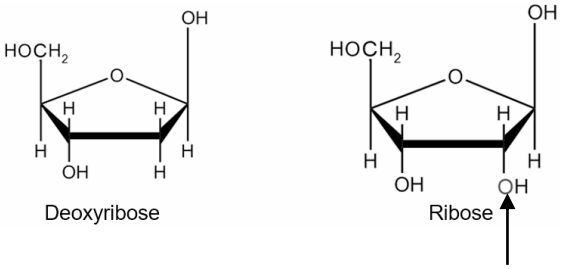



*Five Carbon Sugar*

A sugar is bonded to the base

- In DNA the sugar is _____
- In RNA the sugar is _____

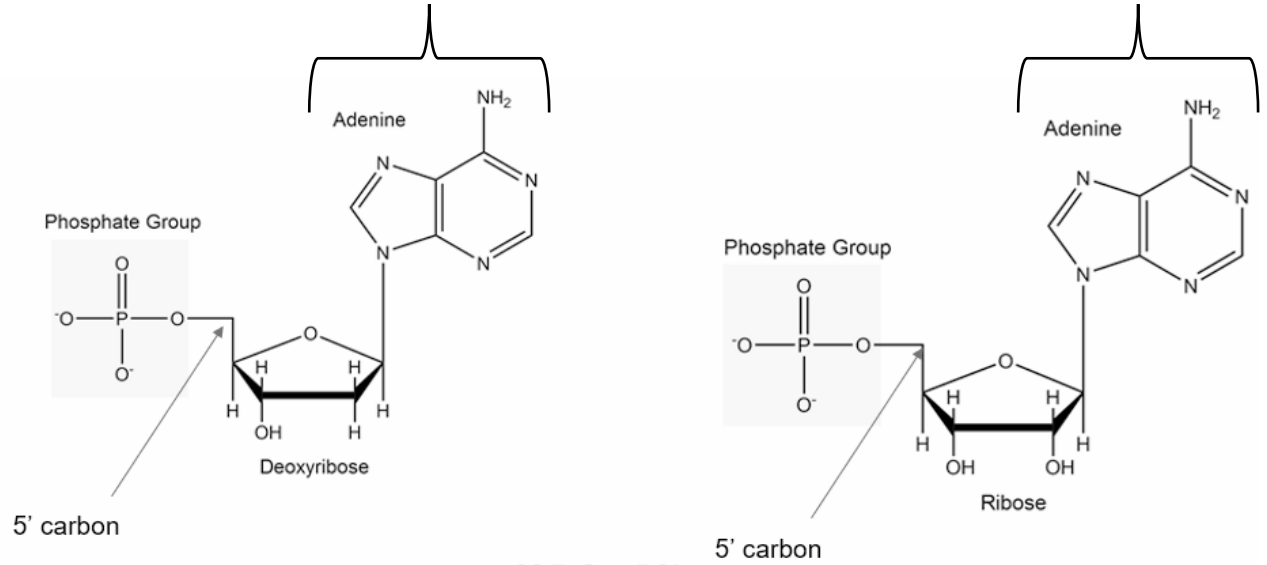
Differ in structure and function




*Phosphate Group*

A _____ group is added to the _____ carbon of the sugar (which is attached to the base) to form a _____

Nucleoside- portion without phosphate group

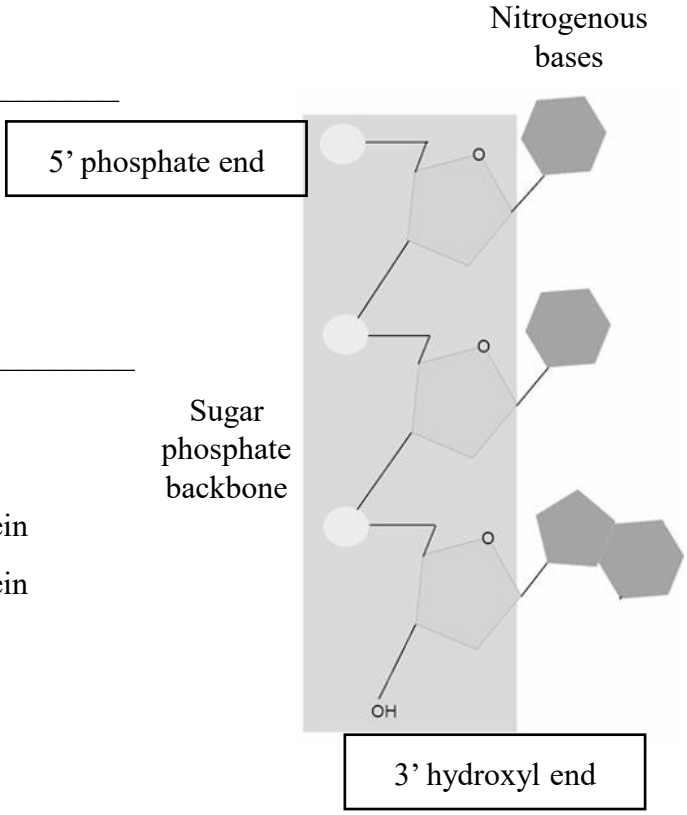



➔Questions?
➔Textbook chapters/pages to review

**Polynucleotides**

_____ groups link adjacent _____

- Phosphodiester linkage
- Directionality
    - 5' to 3'




The sequence of bases along the DNA or mRNA is _____ for each _____

➢ Dictates ____ sequence

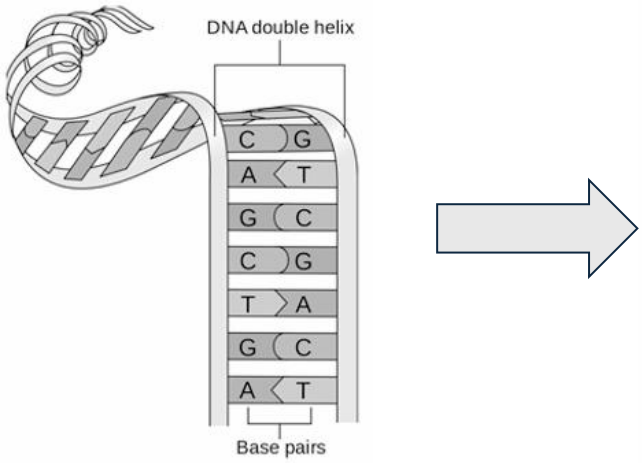
➢ Dictates _____ structure of a protein

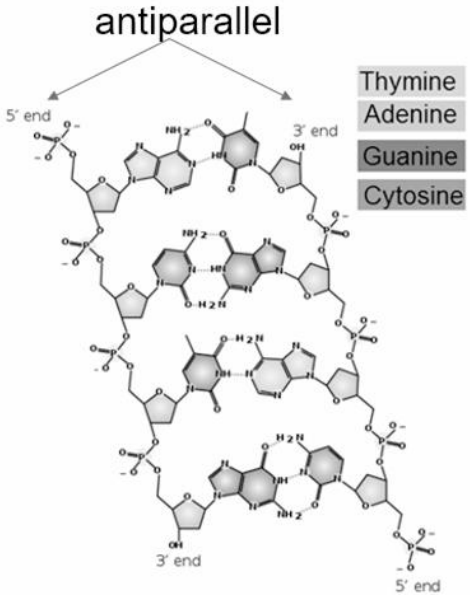
➢ Dictates _____ structure of a protein

**DNA**

Consists of two polynucleotides

- Forms a double helix
    - Strands are _____
    - Held together by _____ bonds between bases
        - Cytosine binds to _____
        - Adenine binds to _____




➔Questions?
➔Textbook chapters/pages to review

**RNA**

_____ stranded polynucleotide

- Variable in shape
    - Due to base pairing within RNA
        - Adenine bonds to _____
        - Cytosine bonds to guanine

**Practice**

1. You are given a segment of DNA: 5'- CATGTCAAC-3'. What is the complementary strand? (Remember to include directionality.)

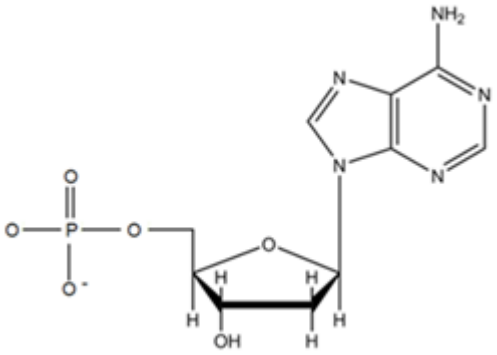
➔Questions?
➔Textbook chapters/pages to review

## Practice Problems: Nucleic Acids

1. What elements make up nucleic acids?

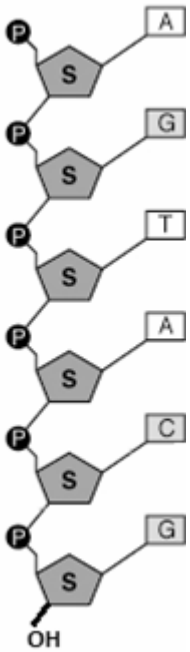
2. What are the monomers of nucleic acids?

3. Using the nucleotide to the right, circle the nitrogenous base in red, the five carbon sugar in green, and the phosphate group in purple.




4. Is the sugar in the nucleotide to the right deoxyribose or ribose? How do you know?

5. Is the nitrogenous base in the nucleotide to the right a pyrimidine or a purine? How do you know?



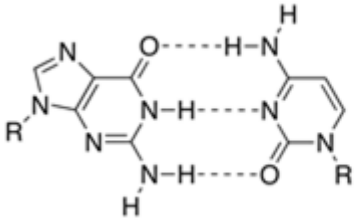

6. What does the term "directionality" refer to when discussing polynucleotides?

7. In reference to question 6, label the ends of the polynucleotide to the left.

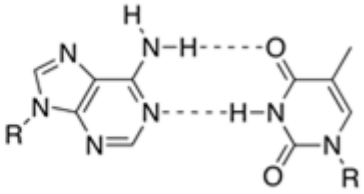
8. What type of reaction occurs to covalently bond nucleotides? Describe the reaction.

9. What is the name of the bond that holds nucleotides together? Label these bonds on the polynucleotide to the left.

10. To which end would nucleotides be added in a growing polynucleotide? Demonstrate this by drawing a nucleotide being added to the polynucleotide chain to the left (*you may choose any appropriate nitrogenous base for the nucleotide*).



*Guanine* *Cytosine*



*Adenine* *Thymine*

11. What type of bond allows for base pairing (*represented by the dashed lines*)? Compare the base pairing between C and G versus A and T.

12. Which set of base pairs do you predict would be more structurally stable? Why?

When DNA is heated, the double strands unwind and separate into single strands due to the breaking of hydrogen bonds between the bases. This process is called denaturation. An experiment was performed where two molecules of DNA were placed in a solution and heated. Both sets of DNA contained 40 base pairs, but each DNA molecule was modified such that one DNA molecule contained only adenine and thymine bases and the other contained only cytosine and guanine bases. Examine the data in the chart below.

| DNA with only A/T | | DNA with only C/G | |
|---|---|---|---|
| Temp (°C) | % single strand | Temp (°C) | % single strand |
| 37 | 0 | 37 | 0 |
| 47 | 23 | 47 | 5 |
| 57 | 52 | 57 | 17 |

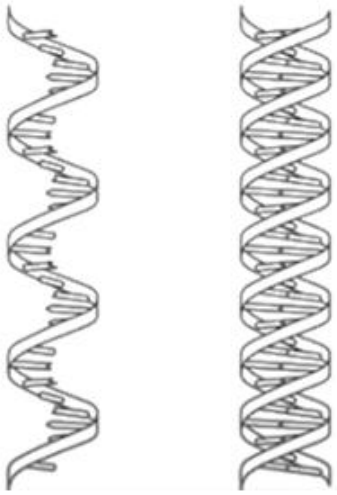
13. Describe the effect that temperature had on each DNA molecule.

14. Propose an explanation for the results in the table above by discussing how changes in structure affect functionality.

15. Using the image to the right, create a list of similarities and differences between the two nucleic acids.

Similarities

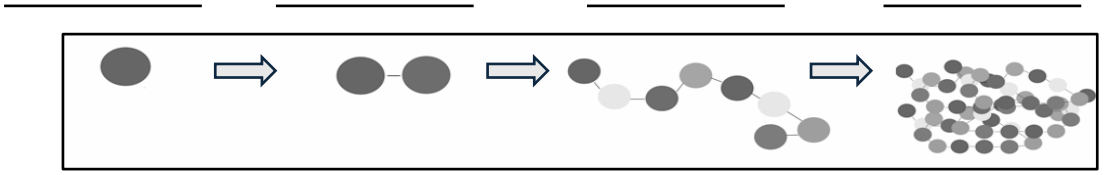
Differences



RNA DNA

**Proteins**

**Formation of a protein**



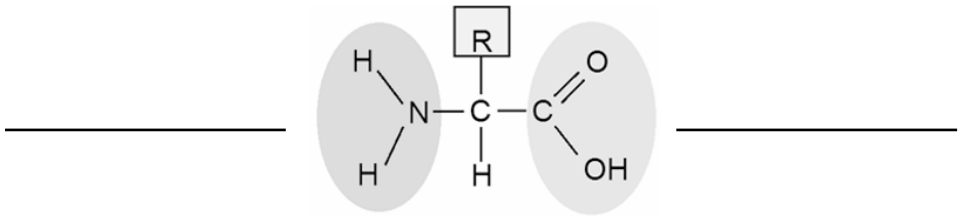
Protein: molecule consisting of _____ (polymers of amino acids) folded into a 3D shape

- Comprised of C, H, O, N, and S
- _____ determines _____

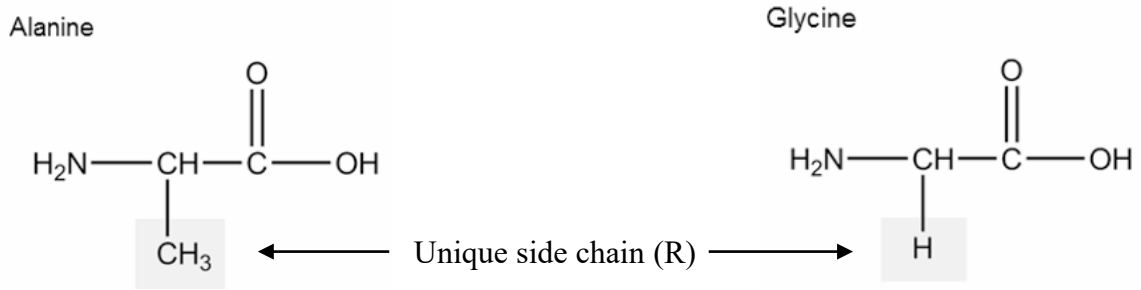
Amino acids: molecules that have an _____ group and a _____ group

- ____ different amino acids

General structure: _____




Examples:

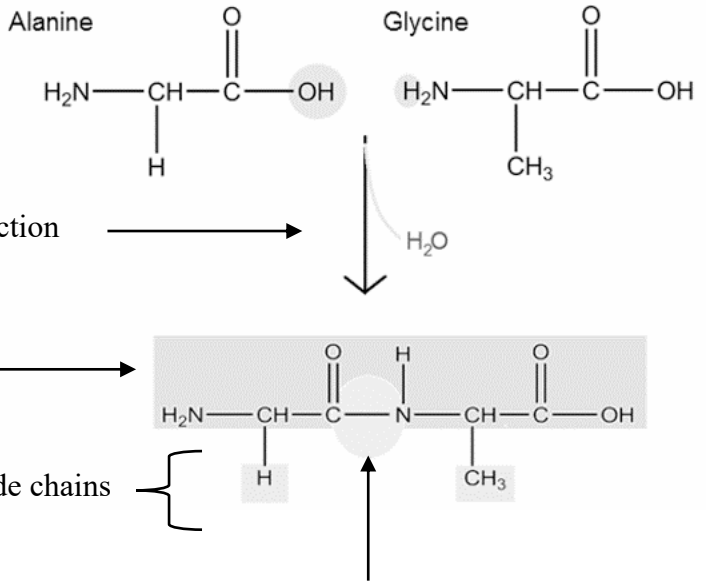



- Each amino acid (AA) has a unique side chain
  - Unique aspects of the AA are based on the side chain's physical and chemical properties
  - Side chains can be grouped as:
    - _____ (hydrophobic)
    - _____ (hydrophilic)
    - _____/_____(hydrophilic)
  - Side chains _____, which determine the _____ and _____ of the protein

➔Questions?
➔Textbook chapters/pages to review

**Formation of Peptide Bonds**

To form a peptide bond, the _____ group of one AA must be positioned next to the _____ group of another AA




**Polypeptides**

Polypeptides: many _____ linked by _____ bonds

- Each polypeptide has a _____ sequence of _____ and _____
  - Each end is chemically _____
  - One end is a free _____ group (N-terminus)
  - One end is a free _____ group (C-terminus)
- The sequence of _____ determines the _____ shape
- When a polypeptide twists and folds (because of ____ group interaction) it forms a _____

Remember: _____ determines _____

*Think, Pair, Share*

How is the unique sequence of AAs determined for a polypeptide?



➔Questions?
➔Textbook chapters/pages to review

**Functions of Proteins**

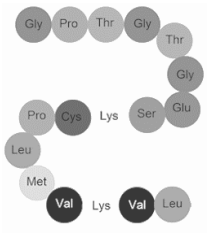
Function of proteins include:

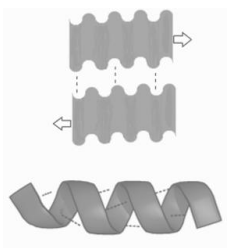
- Antibody-help protect the body from _____
- Enzyme- carry out chemical _____ or assist in creating new molecules
- Messenger- transmit signals (i.e. _____)
- Structural- provide structure and support
- Transport/storage- bind to and carry small atoms and molecules through the body

**Levels of Protein Structure:**

| **Primary** | **Secondary** | **Tertiary** | **Quaternary** |
|---|---|---|---|
| Linear chain of _____<br>• Determined via _____<br>• Dictates secondary and tertiary forms | Coils and folds due to _____ bonding within the polypeptide backbone<br>• **β** pleated sheet- hydrogen bonds between polypeptide chains lying _____ by _____<br>• **α** helix- hydrogen bonding between every _____ AA | _____ folding due to interactions between the _____ _____of the AAs<br>• Reinforced by _____ interactions, _____ bonds, _____ interactions and _____ bridges of the side chains<br>• The covalent bond formed between _____ atoms of two _____ monomers | Association of _____ or more polypeptides<br>• Found in only some proteins |

All four levels of a protein's structure determine the protein's function



➔Questions?
➔Textbook chapters/pages to review

## Practice Problem

1. Cystic fibrosis is a serious, life-threatening disease that affects the lungs and digestive system of affected individuals. This disease results from the deletion of three nucleotides on the Cystic Fibrosis Transmembrane Conductance Regulator (CFTR) gene. This gene codes for a transmembrane protein that regulates ion channels in epithelial tissue. Provide an explanation for how this deletion could result in cystic fibrosis.

## Putting It All Together

Fill in the table below:

| Macromolecule | Elements Involved | Monomer (sub-unit) | Polymer |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

➔Use this space to reflect on topics 4,5, and 6
➔Textbook chapters/pages to review

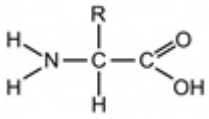
## Practice Problems: Proteins

1. What elements make up proteins?

2. What are the monomers of proteins? Polymers?

3. Why is the word polypeptide not synonymous with the word protein?

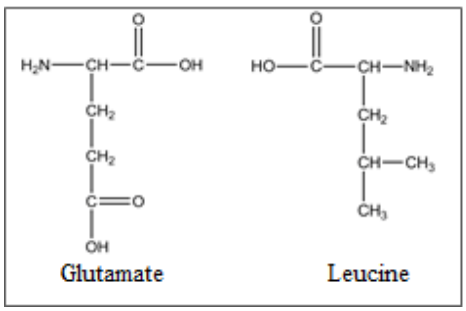
4. The image to the right represents the basic structure of an amino acid. On the image circle and label the two functional groups that all 20 amino acids have. Then, box the variable side chain, which differs between each amino acid.

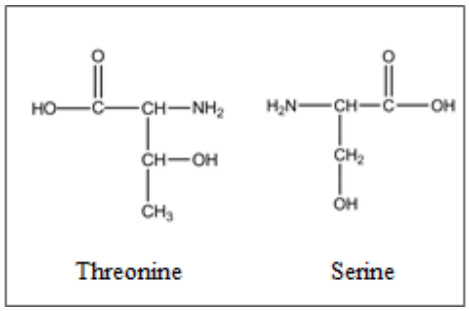


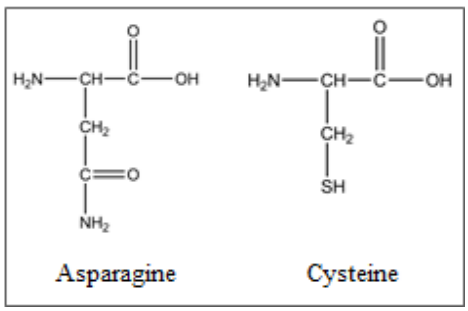
5. R groups can be classified by their chemical properties. Identify the three classifications for R groups and then discuss how the R groups affect the structure and function of a protein.

6. When a protein is folded, which classification of R groups would orient outward (toward the surface/aqueous cellular environment)? Which would orient inward (away from the aqueous cellular environment)? Why?

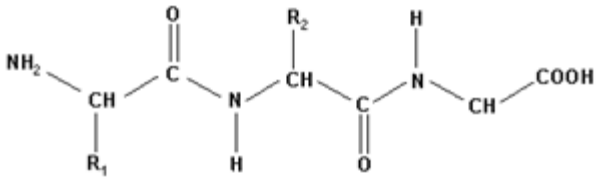
7. Examine the three pairs of amino acids below. Which pair of amino acids is in the optimal position to form a dipeptide? Justify your choice by identifying and describing the reaction that takes place to form peptide bonds.



8. The image to the right represents a growing polypeptide chain. What does directionality refer to in terms of polypeptides? Label the image to the right accordingly.




*Use the chart below to help answer questions 9-12*

| | |
|---|---|
| Polar amino acids | Serine, threonine, cysteine, asparagine, glutamine, tyrosine, lysine, arginine, histidine, aspartate, glutamate |
| Nonpolar amino acids | Glycine, alanine, valine, leucine, methionine, isoleucine, phenylalanine, tyrosine, tryptophan |

9. If an amino acid substitution occurred in a polypeptide chain, predict which option would have the most significant impact on the structure and function of the final protein? Why?
a. Serine is replaced by glutamate
b.Alanine is replaced by lysine
c.Glycine is replaced by valine

Sickle cell anemia is an inherited disorder that affects the shape of red blood cells (*see Figures 1 and 2*). Individuals who have sickle cell anemia have blood that is chronically low in oxygen, and they suffer from frequent infections and chronic pain. Sickle cell anemia is caused by a single nucleotide substitution in the hemoglobin-Beta gene found on chromosome 11. This mutation causes one adenine nucleotide on the hemoglobin-Beta gene to be switched to the nucleotide thymine. This, in turn, causes a change in a single amino acid in the resulting protein that helps form red blood cells. Normal red blood cells should have glutamic acid (glutamate) as the sixth amino acid position in their polypeptide chain, but the mutation switches this glutamic acid to valine. Use this information and the chart above to answer questions 10-12.

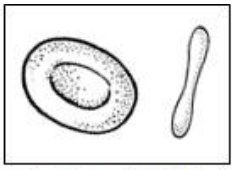


Figure 1: Normal red blood cell (left) versus sickle cell (right)

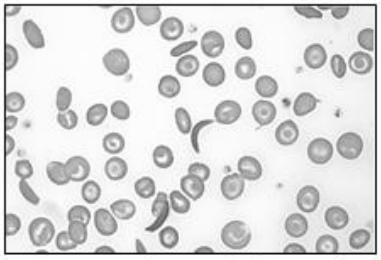


Figure 2: Microscopic image of a blood smear

10. What codes for proteins?

11. In the case of sickle cell anemia, what happens to the gene? To the protein?

12. Propose an explanation for how a single amino acid substitution could cause such a dramatic difference in the final shape of red blood cells.

## Dry Lab: Paper Chromatography

### Introduction

Paper chromatography is a procedure that can be used to identify the amino acids present in an unknown protein sample. Chromatography refers to a variety of laboratory techniques used to separate mixtures. Paper chromatography works by passing a mixture dissolved in a "mobile phase" (the solvent) through a "stationary phase" (the paper). This separates the substance to be measured from other molecules in the mixture and allows it to be isolated. The solvent moves up the paper by capillary action. As the solvent moves up the paper, it carries along any substances dissolved in it.

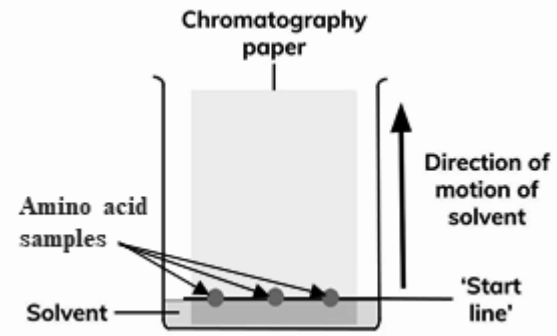



Figure 1: Setup of paper chromatography

In the case of amino acid identification, the amino acids are carried along the paper at different rates for two reasons. First, they are not equally soluble in the solvent. Second, they are attracted, to different degrees, to the fibers in the paper through the formation of hydrogen bonds. Once the solvent has traveled all the way up the paper, the paper strip is dried and sprayed with a 0.5% ninhydrin solution and heated. This allows for the paper to develop. When the paper is fully developed, colors will appear where the amino acids are located. Once done, you can measure the retention factor ($R_f$), which is the ratio of the distance moved by an amino acid to the distance moved by a solvent front using the formula below.

$$R_f = \frac{\text{distance amino acid migrated (mm)}}{\text{distance solvent front migrated (mm)}}$$

| Amino acid | $R_f$ value |
|---|---|
| Alanine | 0.38 |
| Arginine | 0.20 |
| Asparagine | 0.50 |
| Aspartic acid | 0.24 |
| Cysteine | 0.40 |
| Glutamine | 0.13 |
| Glutamic acid | 0.30 |
| Glycine | 0.26 |
| Histidine | 0.11 |
| Isoleucine | 0.72 |
| Leucine | 0.73 |
| Lysine | 0.14 |
| Methionine | 0.55 |
| Phenylalanine | 0.68 |
| Proline | 0.43 |
| Serine | 0.27 |
| Threonine | 0.35 |
| Tryptophan | 0.66 |
| Tyrosine | 0.45 |
| Valine | 0.61 |

### Overview

You are provided 3 samples of unknown dipeptides and must use paper chromatography to determine the amino acid composition of each sample.

### Procedure

1. Cut a piece of chromatography paper and mark a line with a pencil about 1.5 cm from the bottom (start line for the solvent).
2. Make 3 dots along the start line (as seen in figure 1). This is where your dipeptide samples will be placed.
3. Gather three tubes, labeled "samples 1-3," and add each unknown dipeptide to the appropriate tubes.
4. Add 200 µL of 6 N HCl to hydrolyze the samples. Allow the samples to hydrolyze for 20 minutes.
5. Using a pipette, place a single drop of each sample onto the dots marked at the start line.
6. Prepare a beaker by adding the solvent, making sure the top of the solvent does not pass the start line (as seen in figure 1).
7. Place the paper dotted with the samples into the solvent. Allow the paper to develop in the solvent for 20 minutes.
8. Remove the paper from the solvent and allow to fully dry.
9. Spray the dried paper with the 0.5% ninhydrin solution and allow the colors to develop.
10. Once the colors have developed, use a pencil to draw circles around each colored mark, which represents the location of each amino acid.
11. Mark the center of each circle (this will be the distance from the start line to determine how far the amino acid migrated).
12. Locate the solvent front line and mark it by drawing a dashed line across the paper with a pencil (this is the distance the solvent travelled from the start line).
13. Calculate the $R_f$ value for each amino acid. Use the table to the left to identify the amino acids.

**Results**

The results of the paper chromatography can be seen in Figure 2 to the right.

**Calculations**

Use the ruler located at the right side of the paper chromatography to calculate the $R_f$ value for each amino acid in each sample. Show your work below:

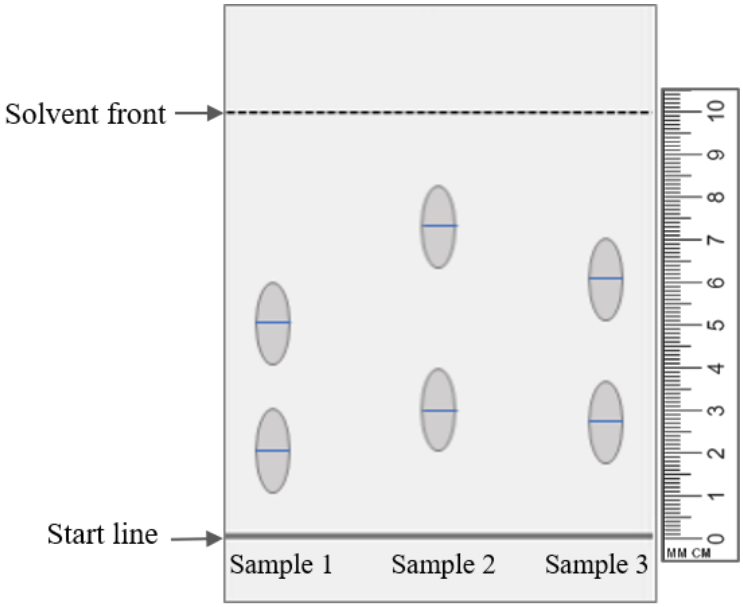



Figure 2: Developed paper chromatography

**Analysis**

1. Referring to the procedure, what is the purpose of exposing the dipeptide samples to a 6N HCl solution?

2. What is the purpose of spraying the paper with a 0.5% solution of ninhydrin?

3. Based on your calculations, what amino acids are in samples 1-3?

4. Once you have determined the amino acid composition of each sample, you are told that each sample was taken from a specific species of bacteria. The dipeptide samples represent the amino acids that are most important to the bacteria's survival and reproduction. You are not told which sample represents which bacteria, but you are given the amino acid composition of the medium that each bacteria grows best in. "Medium" is a solution of nutrients that allow bacteria to survive and reproduce in a lab. Use the table below to determine the species of bacteria that each sample represents.

| Bacterial Species | Medium Composition |
|---|---|
| *E. coli* | 70% arginine, 20% glutamine, 10% threonine |
| *S. aureus* | 50% valine, 10% alanine, 40% serine |
| *S. agalactiae* | 60% glutamic acid, 10% valine, 30% leucine |

## Practice FRQ for Unit 1 Exam

Researchers are investigating the effects of a newly developed pesticide on crop productivity. After application, crops treated with the pesticide appear to have reduced output compared to untreated crops of the same type. Researchers hypothesize that the pesticide is negatively affecting photosynthesis in the treated plants.

To test this, baseline $CO_2$ levels in the leaves of the plants were measured 2 hours before treatment with the pesticide. After applying the pesticide, $CO_2$ levels were measured again at 2 hours post-treatment and 12-hours post treatment. The summarized data is presented in Table 1.

| | **Mean Photosynthetic Rate (µmol $CO_2/m^{-2}/s^{-1}$) ± 2 SEM** | | |
|---|---|---|---|
| **Group** | **2 hours before treatment** | **2 hours after treatment** | **12 hours after treatment** |
| No Treatment | 14.0 ± 1 | 13.0 ± 1 | 14.0 ± 1 |
| Pesticide | 14.0 ± 1 | 4.0 ± 2 | 8.0 ± 2 |

a.

i. **Identify** the independent variable in the experiment. (1 pt)

ii. **State** a null hypothesis for the experiment. (1 pt)

b.

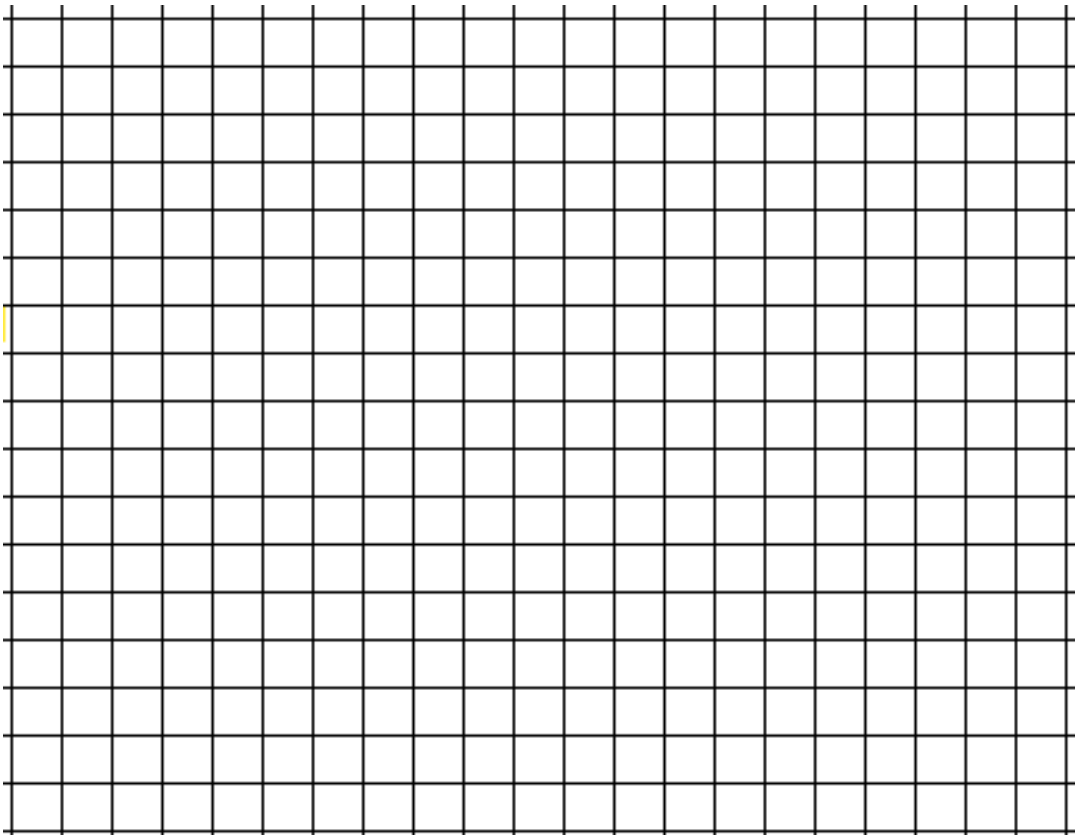
i. Using the template in the space provided for your response, **construct** a line graph that represents the data shown in Table 1. Your graph should be appropriately plotted and labeled. (3 pts)

ii. **Draw** a vertical line on the completed graph to represent when the pesticide was applied to the experimental group. (1 pt)

c. Use the data in Table 1 to **support** the scientists' hypothesis. (1 pt)

Upon further study, researchers found that the pesticide interacts with sulfhydryl groups, functional groups containing sulfur and hydrogen (-SH). The researchers hypothesize that this interaction is causing enzymes critical to photosynthesis to lose function.

d. **Predict** the level of protein structure that is most directly affected by the pesticide's interaction with sulfhydryl groups. **Justify** your prediction. (2 pts)



**Example Grading Rubric**

**(a)**

**i. Identify** the independent variable in the experiment. (1 pt)

- **1 point**: Pesticide treatment/application.

**ii. State** a null hypothesis for the experiment. (1 pt)

- **1 point**: Correctly states a null hypothesis, such as:
  - "The pesticide has no effect on the photosynthetic rate of plants"
  - "There will be no difference in photosynthetic rate between plants treated with the pesticide in comparison to those not treated with the pesticide"

**(b)**

i. Using the template in the space provided for your response, **construct** a line graph that represents the data shown in Table 1. Your graph should be appropriately plotted and labeled. . (3 pts)

- **1 point**: Appropriate labeling of the axis
  - x-axis as time (hours) before/after treatment
  - y-axis as mean photosynthetic rate (µmol $CO2/m^{-2}/s^{-1}$)
- **1 point**: Data are represented as a line graph. Means are accurately plotted.
- **1 point**: Includes accurate error bars to represent ± 2 SEM.

ii. **Draw** a vertical line on the completed graph to represent when the pesticide was applied to the experimental group.

- **1 point**: for correct placement of vertical line to mark when the pesticide was applied to the experimental group.

**(c)** Use the data in Table 1 to **support** the scientists' hypothesis. (1 pt)

- **1 point**: The mean photosynthetic rate of the plants treated with the pesticide are significantly lower than the plants that were not treated (the error bars do not overlap.

**(d) Predict** the level of protein structure that is most directly affected by the pesticide's interaction with sulfhydryl groups. **Justify** your prediction. (2 pts)

- **1 point**: for prediction
  - Tertiary structure
- **1 point**: for justification
  - Sulfur (sulfhydryl groups) form disulfide bonds that help maintain the 3D shape of a protein.

Your score: ____ / 9 Points Total