AP BIOLOGY SUMMER PACKET 2025-2026

This packet is intended to be used as a way to introduce some of the necessary science skills that you will need for the duration of AP Biology, and as a way for you to gain practice with said skills. These skills align with several of the "Science Practices" that are provided in the AP Biology Course and Exam Description manual. As AP Biology is

This goes along with the Nearpod notes:

https://app.nearpod.com/?pin=3DLCF   Use the code: 3DLCF

When you log in make sure you write your first and last name for full credit.

Please complete Parts 1-5 on Notability (which will be submitted on Canvas on the first day) and physically print out Part 6.

Name: ____Date: ____________________

Part 1- CER Practice

Carl's Conspiracies Video- Using the on slide 8 of the Nearpod write down the TWO CER's made:

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2) ____

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Part 2- FRQ Practice

Study each Task verb for the FRQ, you will take a quiz on them during your first week

The following **task verbs** are commonly used in the free-response questions:

Calculate: Perform mathematical steps to arrive at a final answer, including algebraic expressions, properly substituted numbers, and correct labeling of units and significant figures.

Construct/Draw: Create a diagram, graph, representation, or model that illustrates or explains relationships or phenomena. Labels may or may not be required.

Describe: Provide relevant characteristics of a specified topic.

Determine: Decide or conclude after reasoning, observation, or applying mathematical routines (calculations).

Evaluate: Judge or determine the significance or importance of information, or the quality or accuracy of a claim.

Explain: Provide information about how or why a relationship, process, pattern, position, situation, or outcome occurs, using evidence and/or reasoning to support or qualfiy a claim. Explain "how" typically requires analyzing the relationship, process, pattern, position, situation, or outcome; whereas explain "why" typically requires analysis of motivations or reasons for the relationship, process, pattern, position, situation, or outcome.

Identify: Indicate or provide information about a specified topic, without elaboration or explanation.

Justify: Provide evidence to support, qualify, or defend a claim, and/or provide reasoning to explain how that evidence supports or qualifies the claim.

Make a claim: Make an assertion that is based on evidence or knowledge.

Predict/Make a prediction: Predict the causes or effects of a change in, or disruption to, one or more components in a relationship, pattern, process, or system.

Represent: Use appropriate graphs, symbols, words, illustrations, and/or tables of numerical values to describe biological concepts, characteristics, and/or relationships.

State (the null/alternative hypothesis): Indicate or provide a hypothesis to support or defend a claim about a scientifically testable question.

Support a claim: Provide reasoning to explain how evidence supports or qualifies a claim.

Part 3- Lab Safety

To ensure a safe and productive laboratory environment, it is crucial to follow proper safety protocols. By familiarizing yourself with lab safety guidelines, you can protect yourself and others while conducting experiments.

Part 4- Experimental Design in AP Biology

Skill #1: Questioning and Hypothesizing
(Science Practice 3)

You may be familiar with the steps of the scientific method from previous science courses that you have taken at St. John's. These steps are as follows:

Step 1: *Pose a scientific question.*
Step 2: *Come up with a testable hypothesis.*
Step 3: *Design an experiment to test this hypothesis.*
Step 4: *Collect and analyze data.*
Step 5: *Draw conclusions.*

The first two steps of the scientific method are to pose a question about the natural world, and to develop a hypothesis. The first step is fairly straight forward. This could include questions like, "Why do birds fly south for the winter?" or "Why do certain species of butterfly seem more attracted to certain species of flower?" The second step, however, is a bit more complicated.

All good hypotheses must be *testable*. Hypotheses are, after all, the starting points for scientific investigations. To illustrate this, here are a few examples of good and bad hypotheses:

Good Hypotheses: (i.e. testable)

- Exposing plants to low temperature would result in changes in leaf color.
- Aphid-infected plants that are exposed to ladybugs will have fewer aphids after a week than aphid-infected plants which are left untreated.

Bad Hypotheses: (i.e. not testable)

- Our universe is surrounded by another, larger universe, with which we can have absolutely no contact.
- Ladybugs are a good natural pesticide for treating aphid-infected plants.

For each of the following hypotheses, state whether it is good or bad and provide the reasoning behind your response.

1. When there is less oxygen in the water, rainbow trout will suffer from more lice.

2. Lightning is caused by electrical charges moving from the ground to the clouds.

3. People at risk for macular degeneration should eat more leafy greens like kale or romaine lettuce.

4. People with a higher exposure to UV light will have a higher frequency of skin cancer.

Hypothesis Testing **(NOTE: We will be going over this A LOT this year!!!)**

In some cases, scientists will use two hypotheses for a given experiment: a *null* hypothesis and an *alternative* hypothesis. We use these in a "hypothesis test" in which we use statistics to determine the probability that a given hypothesis is true. The definition for each of these hypotheses are as follows:

Null hypothesis (H_0) – a statement that is either believed to be true or is used to put forth an argument unless it can be shown to be incorrect beyond a reasonable doubt. We *typically* attempt to find evidence against our H_0 in our hypothesis test.

Alternative hypothesis (H_a or H_1) – a claim that is contradictory to the H_0 and what we conclude when we reject H_0. We *typically* are attempting to demonstrate the H_a in an indirect way by the use of our hypothesis test.

Additionally, in a mathematical formulation of the null hypothesis, there is often (but not always) an equal sign (=, ≤, or ≥), while the formulation for the alternative hypothesis is typically (but not always) an inequality (≠, <, or >). The following set of negations may help when you are forming your null and alternative hypotheses:

- Null hypothesis: "x is equal to y"; Alternative hypothesis: "x in not equal to y"
- Null hypothesis: "x is at least y"; Alternative hypothesis: "x is less than y"
- Null hypothesis: "x is at most y"; Alternative hypothesis: "x is greater than y"

Let's say, for example, that we wanted to investigate the claim that despite what convention has told us, the mean adult body temperature for healthy individuals is not the accepted value of 98.6°F. The null hypothesis for an experiment to investigate this would be "The mean adult body temperature for healthy individuals is 98.6°F" (or "$\bar{x} = 98.6$°F"). The alternative hypothesis for this experiment would be "The mean adult body temperature for healthy individuals is *not* 98.6°F" (or "$\bar{x} \neq 98.6$°F").

As another example, suppose a medical trial was conducted to test whether or not a new medicine reduces cholesterol by 25%. In this case, the null and alternative hypotheses are:

<u>H_0</u>: The drug reduces cholesterol by 25%. p (or probability) = 0.25
<u>H_a</u>: The drug does not reduce cholesterol by 25%. p ≠ 0.25

As a final example, suppose we wanted to test if college students take less time than five years to graduate from college on average. In this case the null and alternative hypotheses are:

$\underline{H_0}$: College students take an average of 5 years or more to graduate from college.
$\underline{H_a}$: College students take less than 5 years on average to graduate from college.

If we find evidence to suggest that the *observed* average value of the experiment is significantly different from the *expected* average value of our null hypothesis, then we reject the null hypothesis and accept the alternative hypothesis. If we find that there is no significant difference between the observed value and expected value (i.e. any difference seen is due to chance), then we accept the null hypothesis. We determine whether the difference in our observed values and our expected values is significant or not by using a chi-square test *(discussed further in "Skill #4: Statistical Analysis")*.

For each of the given experiments, state the null and alternative hypotheses:

1. Suppose you wanted to test to see if a particular population of cats have 6 offspring on average per litter.

Null Hypothesis: There is no relationship between ____________________________

____ and ____________________________

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Alternative Hypothesis: There is a relationship between ______________________

____ and ____________________________

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2. A team of researchers wants to investigate whether or not money leads to happiness. The team decides to survey 10,000 millionaires about their overall level of happiness.

Null Hypothesis: There is no relationship between ____________________________

____ and ____________________________

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Alternative Hypothesis: There is a relationship between ______________________

____ and ____________________________

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<u>Skill #2: Designing an Experiment</u>
(Science Practice #3)

You may be required to come up with your own experimental design for some laboratory investigations. Before you can do that, however, you must first understand how to set up a *controlled experiment*.

A controlled experiment is one in which you only change one variable across various experimental groups. The variable that you change in an experiment is called your *independent variable* (or *manipulated variable*). The variables that you keep the same (i.e. most variables in an experiment) are called your *controlled variables* or *constants*. The variable that you are measuring or collecting is called your *dependent variable*. The <u>d</u>ependent variable is essentially your <u>d</u>ata.

Often times in a controlled experiment, you also need a *control group* (otherwise known as a *control*) – not to be confused with controlled variables/constants. This is like a non-manipulated experimental group, which will serve as a "baseline" to which you can compare your experimental groups.

As an example, suppose a scientist is conducting an experiment that will test the effectiveness of various types of fertilizers. More specifically, the scientist wants to know which of three fertilizers (F1, F2, and F3) will help his broccoli plants grow at the fastest rate. For this experiment, these would be the notable variables/groups:

<u>independent variable</u>: the type of fertilizer
<u>dependent variable</u>: the rate at which the plant grows or the height of the plant
<u>constants</u>: type of plant, type of soil, amount of soil, amount of sunlight, amount of fertilizer, etc.
<u>experimental groups</u>: broccoli plant with F1, broccoli plant with F2, and broccoli plant with F3
<u>control</u>: broccoli plant with no fertilizer

Note that our control is a broccoli plant without any type of fertilizer. This group, in essence, is a non-manipulated group that we can use as a baseline to which we can compare our experimental group results.

As a final note for this section, there are two general types of controls with which you should be familiar: *negative controls* and *positive controls*. A negative control is one that lacks the independent variable, or at least is minimally affected by the independent variable. This would be like the broccoli plant without any type of fertilizer since the fertilizer is our independent variable. A positive control is one that almost has the independent variable "in full," so to speak. For our broccoli experiment, this could be a broccoli plant treated with a fourth type of fertilizer that has already been proven to be an effective fertilizer. The key to remember here is that controls, whether negative or positive, are used for comparison purposes to get a better gauge on how the independent variable has influenced your other experimental groups.

Now use the following hypothetical experiments to answer the questions below:

A scientist wants to study the effect of different types of music on the behavior of fruit flies (*Drosophila melanogaster*). To test this, the scientist sets up an experiment with four isolated fruit fly populations, each consisting of 100 flies (50 males and 50 females). The first population is observed under the effects of rock music, the second under the effects of classical music, the third under the effects of techno music, and the fourth under the effects of no music. For each trial and for each genre, the music was played for 5 minutes. Each population was observed in a airtight glass container with a controlled amount of atmospheric gases like oxygen, carbon dioxide, and nitrogen. No food was provided to any of the flies during the trials.

1. What is the independent variable in this experiment?

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2. What is the dependent variable(s) in this experiment?

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3. Name three constants in this experiment.

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4. What are the experimental groups in this experiment?

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5. What is the control in this experiment?

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6. What is one way that you would have improved this experimental setup?

7. Suppose that you were to synthesize a new drug that is supposed to relieve pain in patients. To test its effectiveness, you set up a double-blind study where one group of 100 individuals gets the drug in pill form, one group of 100 individuals gets a placebo pill (a pill that does nothing), and one group of 100 individuals gets an Advil® pill that's known to be effective. Identify the negative and positive controls of this experiment.

<u>Skill #3: Data Analysis</u>
(Science Practice #4)

For this class, you will also need to be adept at analyzing data. This means that you will need to be able to interpret the data that you or others have gathered from an experiment by searching for trends and/or patterns in the data, by identifying specific data points of significance, and/or by describing relationships between variables. You will also need to be able to determine how to best present your own data in an experiment (as a bar graph, line graph, pie chart, etc.).

Below are some questions for you to practice analyzing data:

A biology student wanted to determine if there is a relationship between resting heart rate and body height. She gathered information from 12 classmates and constructed the table below.

Student height (cm)	Resting heart rate (beats per minute)
155	60
156	65
156	78
165	72
170	67
175	62
175	80
180	64
180	73
190	68
194	78
195	63

1. Which of the following is best supported by the data in the table? *(Circle one.)*

    a. The taller the student, the higher the resting heart rate.
    b. The shorter the students, the higher the resting heart rate.
    c. A higher resting heart rate results in student growth.
    d. There is no direct correlation between height and resting heart rate.

2. Which type of graph/chart would you use to show the trends in this data? *(<u>Note</u>: Multiple answers accepted here.)*

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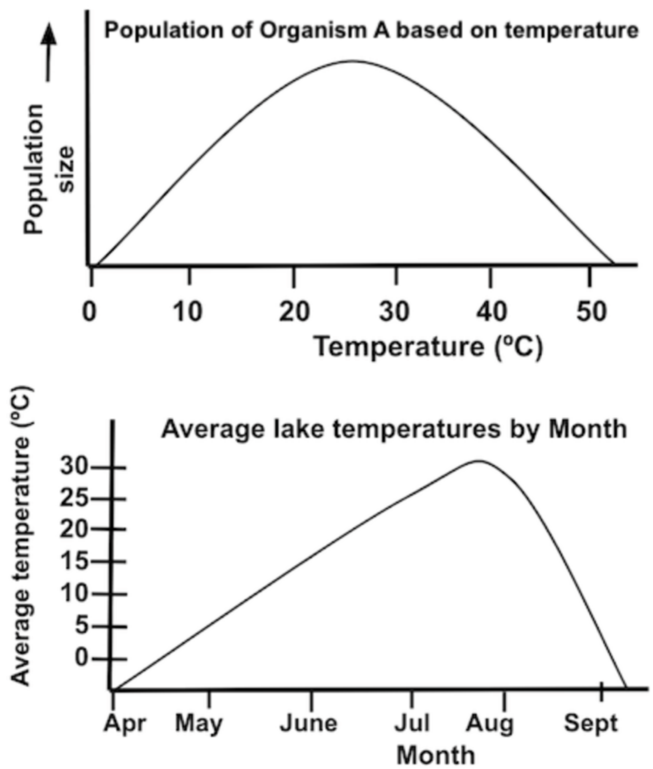
The graphs below show the population size of Organism A in a local lake, and the average temperatures of the lake by month.



3. What type of graphs or charts are shown in the figure above? *(Circle one.)*

    a. bar graphs
    b. pie charts
    c. line graphs
    d. histograms

4. During which month would you expect the Organism A population to be the greatest? *(Circle one.)*

    a. August
    b. May
    c. June
    d. July

Part 5- STATS in AP Biology

Skill #4: Statistical Analysis
(Science Practice #5)

The data that you gather in any experiment is not always going to give you clear results. In fact, data in the biological sciences (notably genetics) can get very messy at times. Sometimes we might get copious amounts of data but cannot immediately tell if the data shows a significant trend or not. This is where we use statistical tests and mathematical formulas to analyze and interpret the data.

For this course, you will need to be able to perform mathematical calculations, which include means, rates, ratios, and percentages, among other mathematical equations in the curriculum (those specific equations will be addressed later in the course). You will also need to be able to use confidence intervals and/or error bars (both determined using standard errors) to determine whether sample means are statistically different. Furthermore, you while need to be fluent in the use of chi-square hypothesis testing.

Means

The mean value is just another way of saying the average value. You find the mean of a given set of values by finding the sum of all of the values and dividing the sum by the total number of values. In other words, you would use the following equation:

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

In this equation, $\bar{x}$ represents the mean value, x_i represents a particular value in the data set, *n* represents the number of values in the data set, *i* indicates which value you are referring to, and $i = 1$ indicates that you are starting with the first value in the data set. The Σ symbol represents a summation (i.e. you will be adding the values together).

As an example, let's say that you are given the following data set:

2, 6, 7, 13, 16, 20, 25, 27, 30, 34

Your values would therefore be: n = 10, x_1 = 2, x_2 = 6, x_3 = 7, x_4 = 13, x_5 = 16, x_6 = 20, x_7 = 25, x_8 = 27, x_9 = 30, and x_{10} = 31. So, our calculation would look something like this…

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$\bar{x} = \frac{1}{10}(2 + 6 + 7 + 13 + 16 + 20 + 25 + 27 + 30 + 34)$$

$$\bar{x} = 18$$

(*Note:* Calculating rates, ratios, and percentages will be not be covered in this packet. If you would like to review these concepts, please see your instructor.)

Variance

Before you can understand how to generate error bars using the standard error of the mean, you must first understand the concepts of variance and standard deviation. Let us start with variance:

Variance measures how far a set of numbers are spread out from their average value. The formula used to calculate variance is…

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

Now let us consider variance in the context of a simpler data set:

5, 10, 15

Here, n = 3, x_1 = 5, x_2 = 10, x_3 = 15, and $\bar{x}$ = 10. We would therefore calculate the variance from the mean as follows:

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

$$s^2 = \frac{(5-10)^2 + (10-10)^2 + (15-10)^2}{3-1}$$

$$s^2 = 25$$

Here, the variance is 25. If we were to consider a data set like 9, 10, and 11, however, we would calculate a much smaller variance value s^2 = 1, even though the mean value of this data set is the same as that of the data set above ($\bar{x}$ = 10). This is because the values of the first data set is much more spread out than the values of the second data set.

Standard Deviation

Good news! Now that you understand how to calculate variance, understanding how to calculate standard deviation is a lot easier. This is because standard deviation is just the square root of the variance value…

$$s = \sqrt{s^2}$$

…or how you will see it on the "AP Biology Equations and Formulas" sheet on the AP exam…

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

The standard deviation essentially gives us the same information as the variance, but the values are much better to work with. If we were to consider our example from earlier where our variance was 25, our standard deviation would only be 5 – a much better number considering our data set consisted of numbers like 5, 10, and 15.

Standard Error of the Mean

Now that we understand variance and standard deviation, we can now understand the standard error of the mean. The standard error of the mean gets calculated using the following equation:

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

If you recall, *S* represents the standard deviation value, and *n* represents the number of values that there are in the data set. Therefore, if we consider our earlier data set of 5, 10, and 15, we would calculate the standard error of the mean as follows:

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}} = SE_{\bar{x}} = \frac{5}{\sqrt{3}}$$

$$SE_{\bar{x}} = 2.9$$

In a nutshell, standard error shows you how good your data is. If you think about it, *n* represents the number of data points that we collect in an experiment, and the standard deviation (*S*) represents how spread out your data is from the mean. So, if your data is not spread out very much (i.e. a low standard deviation) and you have a lot of data points, you should expect a relatively low standard error indicating that you have good data. On the contrary, if your data is very spread out (i.e. a high standard deviation) and you only have a few data points like the example that we've been working with, you should expect a relatively high standard error. This, in turn, would indicate that your data is not the best.

Here are some useful videos if you are still struggling with the concepts of variance, standard deviation, and standard error of the mean:
"(AP Biology) Normal Distribution, Variance, and Standard Deviation"
https://www.youtube.com/watch?v=Uwixu5zbGcg&t=13s
"(AP Biology) Standard Error of the Mean"
https://www.youtube.com/watch?v=wZi4p2QIb34&t=9s

Now that you understand the concepts of means, variance, standard deviation, and standard error, answer questions 1-5 using the given data set:

10.9, 11.9, 12.2, 12.2, 12.9, 12.6

Be sure to show all of your work for questions 1-4, and ***draw boxes around your final answers.***

1. What is the **mean** value of the given data set?

2. Calculate the variance of the data set.

3. What is the standard deviation of this data set? When showing your work, you may use the variance value that you calculated in question 2.

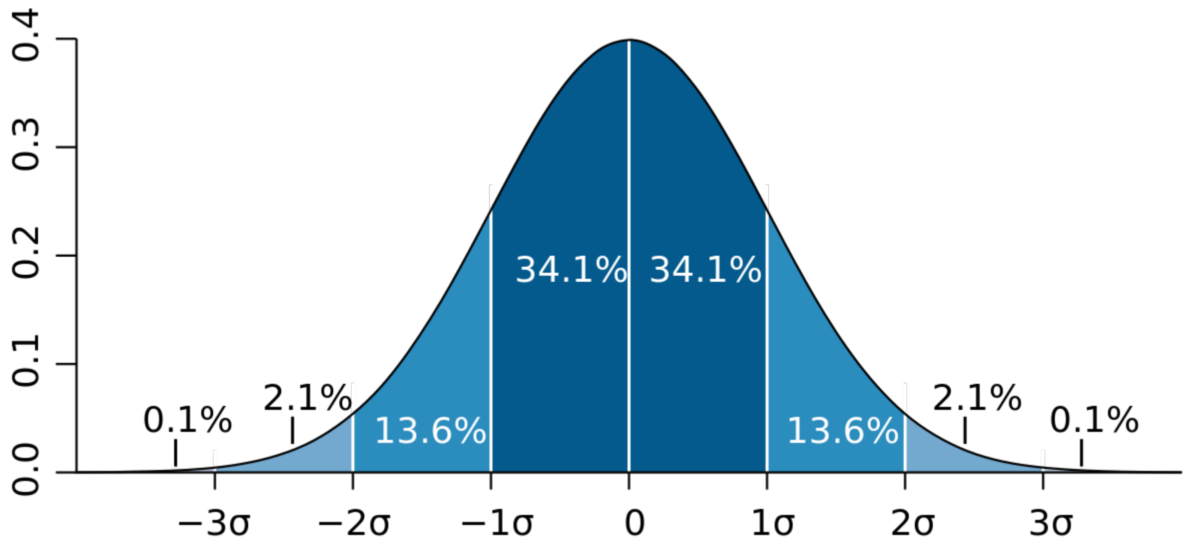
4. Calculate the standard error of the data set.

5. If you were to compare the standard error of this data set to the standard error from the earlier example ($SE_{\bar{x}} = 2.9$), which one indicates a "better" data set? Justify your answer and elaborate fully in your response.

Normal Distribution

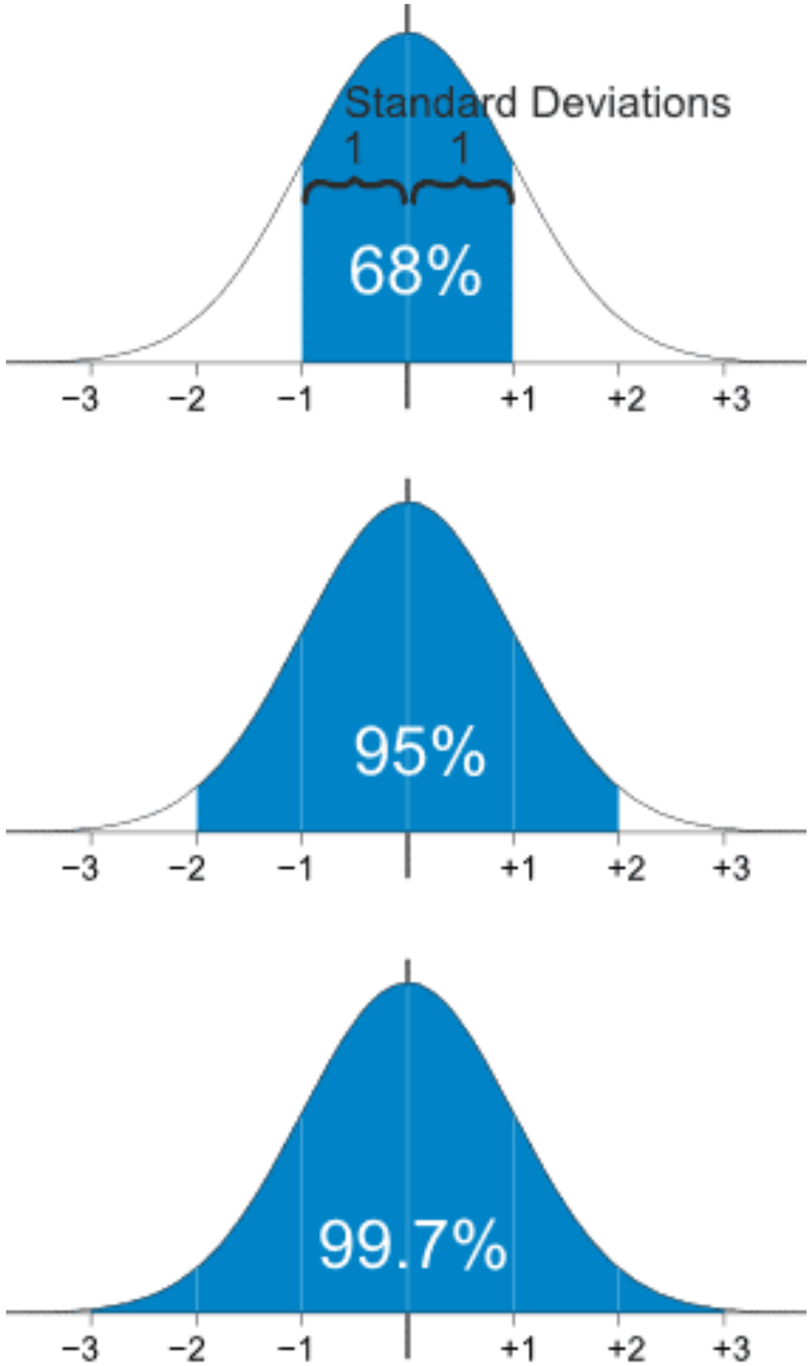
Before we wrap up this section on standard deviation and standard error of the mean, I wanted to discuss two final concepts: *normal distribution* and *error bars*.

A *normal distribution curve* is a graph that shows a continuous probability distribution of all of the data points collected relative to the mean, taking the form of a bell curve. An example of a normal distribution curve is shown below:

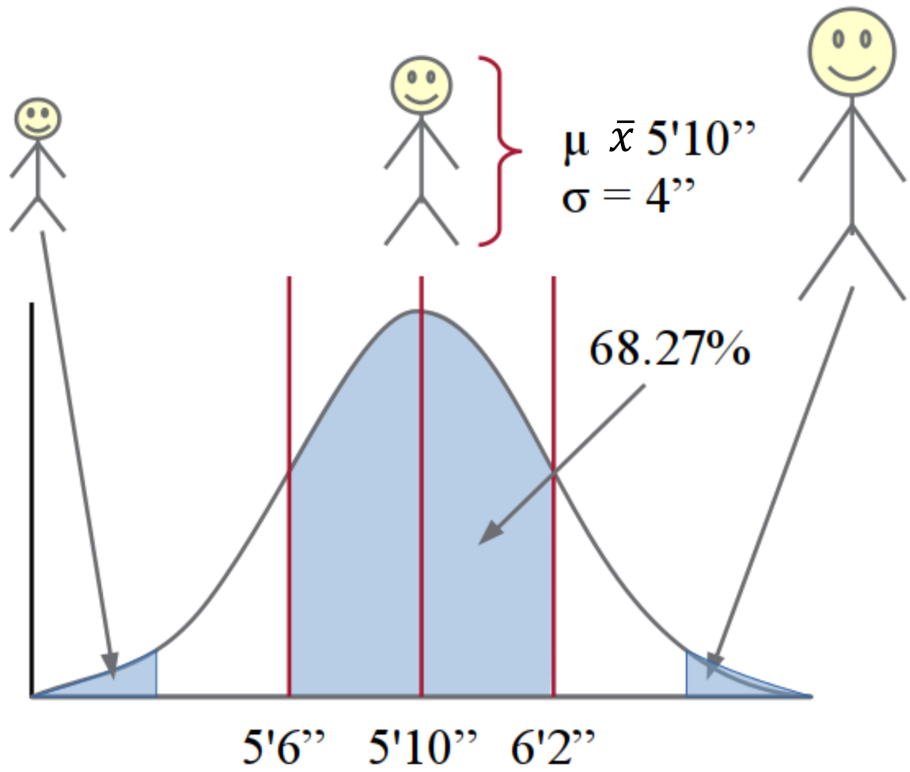


For any normal distribution curve, the x-axis value where the curve peaks represents the mean value ($\bar{x}$) of the experiment, and the area under the curve represents all of the data points used to calculate that mean. The y-axis, on the other hand, typically represents the number of data points for any given x-axis value. Notice how as you move farther and farther away from the mean value, you see fewer and fewer data points. This is because most of the data points in any given experiment (especially if you have collected a lot of data points) will normally fall closer to the mean rather than farther. We will deal with a more specific example in a little bit using male heights, which will hopefully help to clarify these concepts a bit more.

A symbol that you may not recognize on this graph is the Greek letter, σ, or sigma (lowercase). In this circumstance, the σ is used to represent standard deviation (*s*). As you can see from the area under the curve, approximately 68.2% of the data points would fall within plus or minus (±) one standard deviation from the mean. Furthermore, if you were to add up all of the percentages between -2σ and 2σ, you would see that approximately 95.4% of the data points normally fall between ± two standard deviations from the mean. Below is a figure that helps to clarify this concept.



As an illustrative example, suppose that the mean height of males in America is 5'10". That being said, however, not all males in America are going to be 5'10" – some will be taller than that, while others will be shorter. Chances are, however, that the distribution of male heights in America are going to follow a normal distribution. Assuming that we calculated the standard deviation of these height values to be 4", we would expect the distribution of male heights to resemble the following:



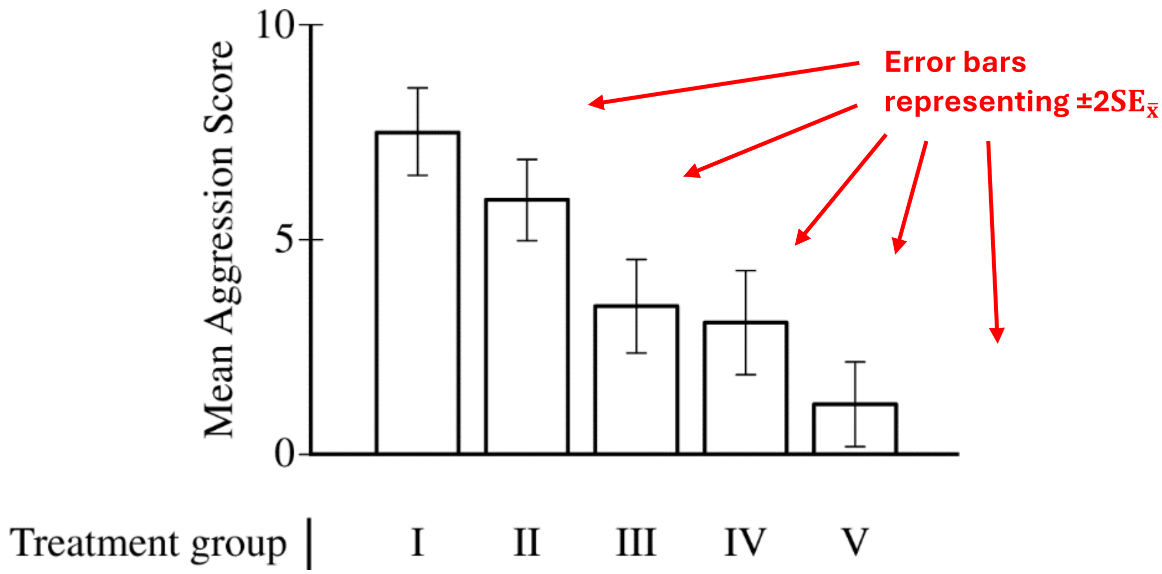
Notice in the above normal distribution curve that about 68% of males fall within one standard deviation of the mean (5'6" to 6'2"). Also notice how only a very small percentage of individuals are significantly taller or shorter than the mean. If we were to move out further from the mean, now considering ±2 standard deviations, or all of the males between 5'2" and 6'6", we would be encompassing approximately 95% of all men in America.

Error Bars

Building off of the prior concept of normal distribution, it turns out that standard error works in very much the same way as standard deviation…

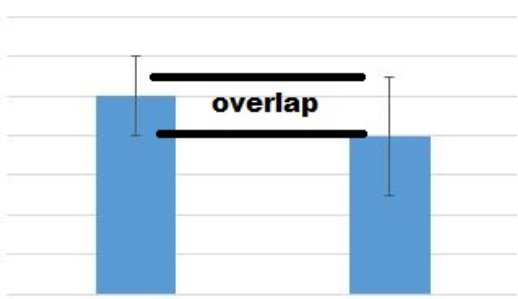
To clarify this point, we know that ±2 standard deviations encompasses approximately 95% of the data points used to calculate the mean. In the same sense, ±2 standard error values ($\pm 2SE_{\bar{x}}$) gives us a 95% confidence interval; meaning that if we ran the experiment again, collected tons of data points, and averaged them all together, we could be 95% confident that the mean would fall within that $\pm 2SE_{\bar{x}}$ range.
Error bars (typically representing $\pm 2SE_{\bar{x}}$) are often times used when plotting mean values on a graph to communicate to the viewer how reliable those mean values are (refer to the error bars shown in the graph below). Remember, if we ran the experiment again, we can be 95% confident that we would get a mean value that falls within $\pm 2SE_{\bar{x}}$ of the original mean. Because of this, mean values

on a graph with relatively small error bars can be seen as reliable, while those with large error bars can be seen as unreliable or inconclusive.

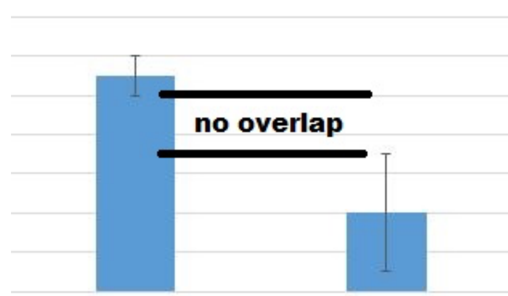


Beyond this point, error bars can also be used to quickly assess whether or not two different means are significantly different from one another by simply looking for overlap. If two different $\pm 2SE_{\bar{x}}$ error bars overlap, we do not consider the two means significantly different from one another. If the error bars do not overlap, we can consider the two mean values significantly different from one another.

As an example, consider the above figure taken from an actual AP Biology question. Looking at this figure, we can say that the mean aggression score of treatment group I *was not* significantly different from that of treatment group II because their error bars overlap with each other. That being said, we can say that the mean aggression score of treatment group I *was* significantly different from that of treatment groups III, IV, and V because of the lack of error bar overlap. Use the following figure as a reference:



No significant difference between the means.



Significant difference between the means

With your new knowledge of normal distribution and error bars, please answer the following question, use the following table to answer the following set of questions…

Table 1. Effect of Paclitaxel Concentration on Percent of Mitotic Cells That Were Tripolar

Concentration of Paclitaxel (nM)	Average Percent of Mitotic Cells ($\pm 2SE_{\bar{x}}$)
0	0.0 ± 0.0
2	17.0 ± 3.0
4	48.0 ± 3.5
6	65.0 ± 5.0
8	70.0 ± 4.0
10	50.0 ± 2.0

c. Using the template provided on the following page, **construct** an appropriately labeled graph that represents the data shown in Table 1. Based on the data, **determine** the concentration(s) of paclitaxel that is (are) most effective in causing tripolar cell division. (Note: This is an actual AP Biology question.)

d. According to your graph, was there a significant difference between the average percent of tripolar mitotic cells for the 4 nM paclitaxel treatment and the 6 nM paclitaxel treatment? How do you know?

Here is a useful video if you are still struggling with the concept of error bars:
"Standard Deviation and Standard Error of the Mean"
https://www.youtube.com/watch?v=3UPYpOLeRJg

Chi-Square Hypothesis Testing

Suppose you were to flip a coin 100 times. Because there is a 50/50 shot of getting either heads or tails, you would probably expect to get heads 50 times and tails the other 50 times. Let's say, however, that you were to instead get heads 54 times and tails 46 times. At this point, you might be wondering if the difference between your *observed* values (54 heads and 46 tails) and your *expected* values (50 heads and 50 tails) is due to chance, alone, or if the difference is significant enough to indicate that there may be an outside variable causing the difference that we see. To determine whether this is chance or not, we use the **chi-square test**.

The chi-square test is a statistical formula that can be described as follows:

$$\chi^2 = \sum \frac{(o-e)^2}{e}$$

In this equation, "*o*" represents your *observed* value, "*e*" represents your *expected* value, and χ^2 represents your *chi-square* value. Once you have calculated your chi-square value, you will use a special **chi-square table** to determine whether or not your observed and expected values are significantly different from one another. The following image shows the chi-square table that you will be given on the AP Biology exam.

Chi-Square Table

p value	Degrees of Freedom							
	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.81	9.49	11.07	12.59	14.07	15.51
0.01	6.63	9.21	11.34	13.28	15.09	16.81	18.48	20.09

On this table, you will note that there are two new variables that we have to consider: degrees of freedom (DF) and *p* values (or "probability" values). You can calculate the degrees of freedom for your experiment by determining your number of possible outcomes and subtracting 1. So, if we consider our earlier example, where we had two possible outcomes (heads or tails), we would only have 1 degree of freedom. The *p* value, on the other hand, will be the final value that we determine by the end of the test, and it will allow us to determine whether or not the difference in the observed and expected values is simply due to chance or rather due to something other than chance (we will get back to *p* values in a little bit).

In addition to degrees of freedom and *p* values, the chi-square table also includes *critical* values ($\chi^2{}_C$). The critical values are represented by all of the numbers in the table that are neither degrees of freedom nor *p* values (e.g., 3.84, 6.63, 5.99, 9.21, etc.).

So how do we use this table? Well, let's say that we calculate our chi-square value (χ^2) to be 1.33 for a separate coin-flipping experiment. As previously explained, we know our degrees of freedom is 1 (2 possible outcomes – 1). Using this information, we go to the chi-square table, and under the column for 1 degree of freedom, we look for the critical value ($\chi^2{}_C$) that is closest to our chi-square value (χ^2). In this case, the closest critical value to our chi-square value of 1.33 is 3.84 (rather than 6.63) for 1 degree of freedom. We then use our critical value to determine our *p* value, which is 0.05 according to the table. If the *p* value for a chi-square test ends up being 0.05 or above, we say that the difference between the observed and expected value is simply due to chance, alone. If the *p* value ends up being less than 0.05 (i.e., 0.01), then we say that the difference is due to something other than chance. So, because our *p* value is 0.05 for this hypothetical experiment, we can conclude that the difference between our observed and expected values was simply due to chance.

Now let's reconsider our earlier coin flip example where our observed values were 54 heads and 46 tails, and our expected values were 50 heads and 50 tails. Our null and alternative hypotheses, in this case, would be as follows (refer back to "Hypothesis Testing" if you are fuzzy on these terms):

H_0: The difference that we see between the observed and the expected values can be attributed to chance, alone (i.e., there is not a significant difference between the two values); *p* value ≥ 0.05

H_a: There is a statistically significant difference between the observed and expected values; *p* value < 0.05

We then calculate the chi-square value as follows:

$$\chi^2 = \sum \frac{(o-e)^2}{e}$$

$$\chi^2 = \frac{(54\,H - 50\,H)^2}{50\,H} + \frac{(46\,T - 50\,T)^2}{50\,T}$$

$$\chi^2 = 0.64$$

Now that we've determined our chi-square value ($\chi^2 = 0.64$), and we know our degrees of freedom (DF = 1), we then can go back to the chi-square table to determine our critical value and, subsequently, our *p* value…

Chi-Square Table

p value	Degrees of Freedom							
	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.81	9.49	11.07	12.59	14.07	15.51
0.01	6.63	9.21	11.34	13.28	15.09	16.81	18.48	20.09

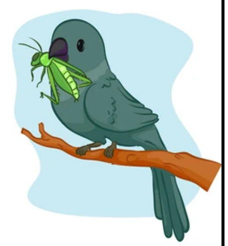
As you can see, we can determine that our critical value is 3.84 because that is the value closest to our chi-square value of 0.64, and therefore our *p* value would be 0.05. Because our *p* value is 0.05 or greater, we have failed to reject our null hypothesis (H_0), and can therefore conclude that the difference between our observed values (54 heads and 46 tails) and our expected values (50 heads and 50 tails) was simply due to chance rather than something else (like one side of the coin being heavier than the other).

Here is a useful video if you are still struggling with the concept of the chi-square test:
"Chi-squared Test"
https://www.youtube.com/watch?v=WXPBoFDqNVk

NOTE: WE'LL BE DOING A LOT OF PRACTICE WITH CHI-SQUARE TESTING

Part 6: Unit 8: Ecology Reading Guide

Topics:
1. Behavioral Ecology
2. Ecosystems and Energy
3. Populations
4. Community Ecology
5. Biodiversity and Disturbances to Ecosystems



Annotation Key

All students are expected print out this Reading Guide, read AND annotate this reading guide. Students will **CIRCLE** unfamiliar words and **STAR** key ideas/facts. Write a **QUESTION MARK (?)** next to anything that confuses you. In addition, on loose-leaf paper lined paper, students will:

(1) Re-write and **highlight in Pink** all AND **vocabulary words and Definitions.**

(2) Re-write and **highlight in Yellow** all key equations/formulas

(3) **Summarize** each topic in their own words

***Topic #1*: Behavioral Ecology**

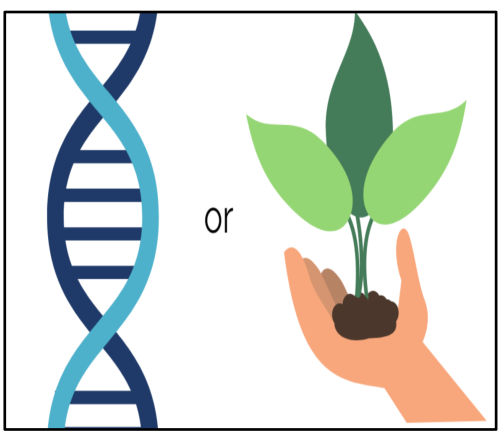
Introduction to Behavioral Ecology

Behavioral ecology is the study of how organisms interact with their environment through behavior. It seeks to understand the evolutionary significance of behavior and how it contributes to survival and reproductive success. Animals exhibit both **individual and social behavior patterns**, which are shaped by genetic and environmental influences.

Ethology: The Study of Behavior

Ethology is the scientific study of animal behavior, with a focus on the mechanisms and evolutionary significance of behaviors. **Behavior** is defined as the observable actions of an organism in response to its environment. Understanding behavior involves distinguishing between **proximate causes** (immediate stimuli and mechanisms triggering behavior) and **ultimate causes** (evolutionary explanations for why a behavior exists).

Nature vs. Nurture in Behavior

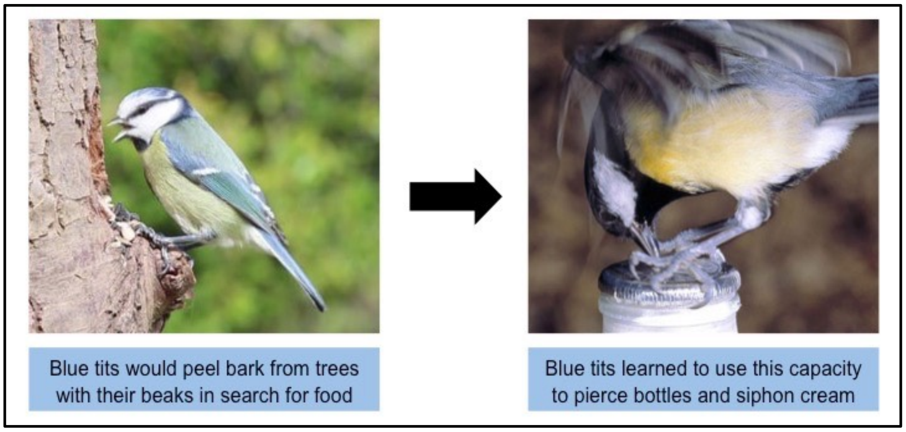


Behavior results from a combination of genetic programming (**nature**) and environmental influences (**nurture**). While some behaviors are **innate** and encoded in DNA, others are **learned** through experience. Importantly, **behavior is subject to natural selection**, meaning behaviors that enhance survival and reproductive success tend to persist in populations over generations.

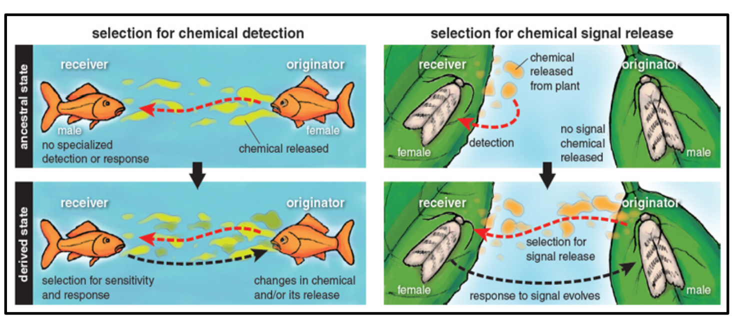
Types of Behavior

Innate behaviors are genetically controlled and exhibited in nearly all individuals of a species. These behaviors do not require learning and are often crucial for survival. Examples include:

- **Fixed Action Patterns (FAPs):** Sequences of unchangeable, instinctive behaviors triggered by a stimulus. Example: A goose retrieving an egg back to its nest.



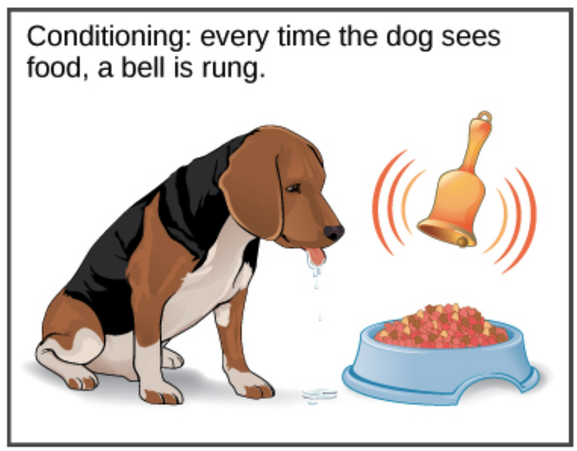
- **Migration:** Seasonal movement of animals, often influenced by environmental cues such as daylight and temperature.
- **Signals and Communication:** Organisms use different signals to convey information:
  - **Visual** (e.g., warning coloration in frogs)
  - **Auditory** (e.g., bird songs, whale calls)
  - **Tactile** (e.g., grooming in primates)
  - **Electrical** (e.g., electric fish communication)
  - **Chemical** (e.g., pheromones used by ants and bees)
  - **Stimulus-Response Chains:** A series of behaviors in response to sequential stimuli.



- **Body Movements & Directed Movements:**
  - **Kinesis:** A non-directional response to a stimulus (e.g., increased activity in pill bugs in humid environments).
  - **Taxis:** A directed movement toward or away from a stimulus:
    - **Phototaxis:** Movement in response to light
    - **Chemotaxis:** Movement in response to chemicals
    - ***Geotaxis:*** Movement in response to gravity

Learned Behaviors *develops through experience and environmental interaction. They include:*

- **Imprinting:** Learning that occurs during a critical period and is often irreversible (e.g., ducklings following their mother).
- **Spatial Learning:** The ability to recognize landmarks to navigate the environment.
- **Cognitive Maps:** Some animals create mental representations of their surroundings for navigation.
- **Associative Learning:** Learning by linking one stimulus with another (e.g., classical conditioning in Pavlov's dogs).
- **Social Learning:** Learning by observing and imitating others (e.g., young chimpanzees learning to use tools).



<u>Natural Selection and Behavior</u>

Behaviors that enhance survival and reproduction are favored by natural selection.

- **Foraging Behavior:** Efficient food-seeking strategies increase an organism's energy intake while minimizing risks.
- **Mating Behaviors & Sexual Selection:**
  - **Sexual Dimorphism:** Differences in appearance between males and females, often due to mating competition.
  - **Mating Systems:** Include monogamy (one mate) and polygamy (multiple mates).

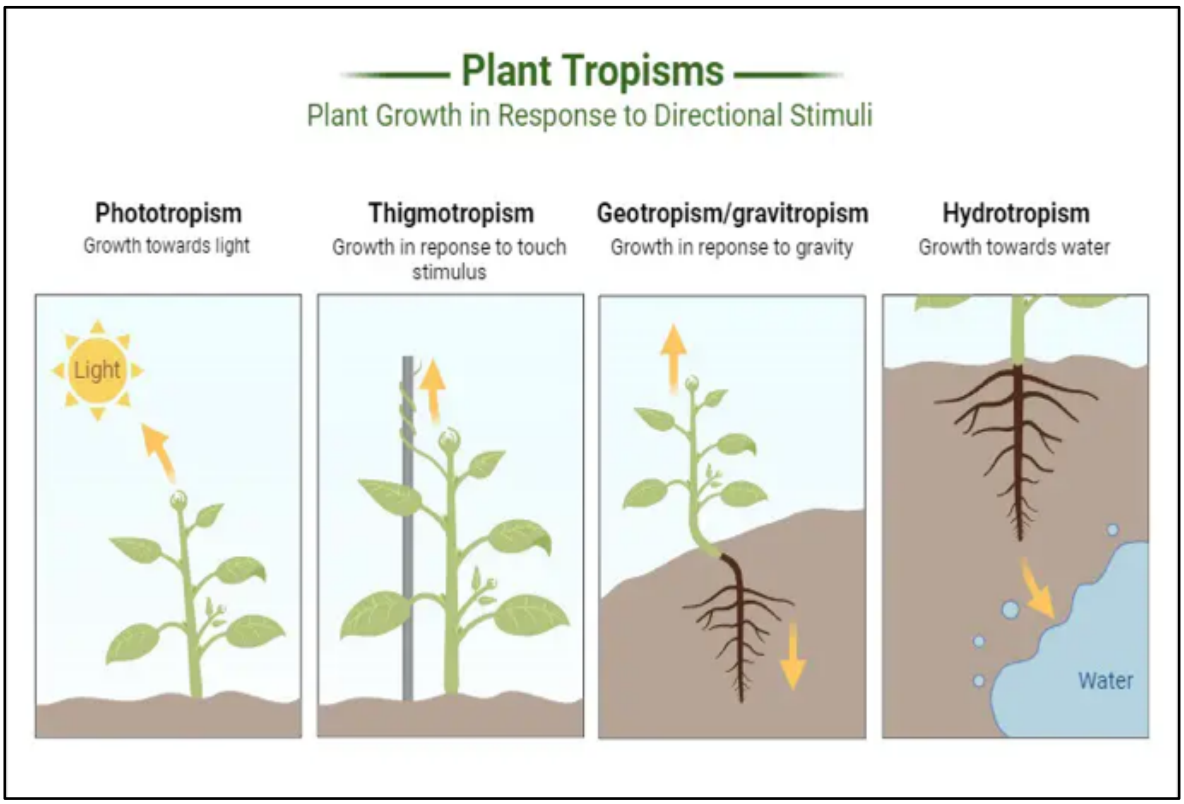
Wrens *(male on left)*	Ducks *(male on left)*	Peacock *(left)* + Peahen *(right)*

- **Cooperative Behaviors:**
  - **Altruism:** Behaviors that benefit others at a personal cost (e.g., worker bees sacrificing reproduction for the colony).
  - **Kin Selection:** Altruistic behavior that benefits relatives, increasing shared genetic fitness.

Responses in Plants

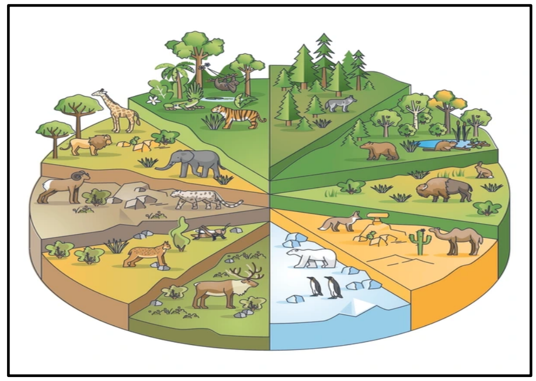
Although plants lack nervous systems, they respond to environmental stimuli through physical and chemical mechanisms:

- **Phototropism:** Growth in response to light, regulated by hormones like auxin.
- **Photoperiodism:** Changes in physiological activity based on seasonal light availability (e.g., flowering in response to day length).
- **Physical Defenses:** Thorns, bark, and trichomes help protect plants from herbivores.
- **Chemical Defenses:** Plants produce toxins or distasteful compounds to deter predators (e.g., alkaloids in tobacco).
- **Soil Composition Influence:** Nutrient availability in soil affects plant growth and development, impacting ecosystem interactions.



***Topic* #2: Ecosystems and Energy**

Introduction to Ecosystems

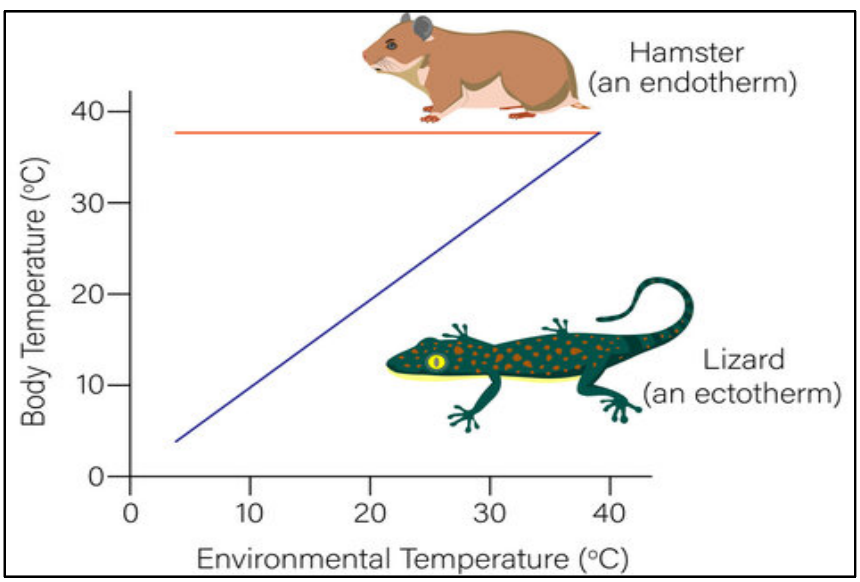


An **ecosystem** consists of all the living (**biotic**) and nonliving (**abiotic**) factors in a given area. Organisms interact with both components, influencing energy flow and nutrient cycling.

Metabolic Rate and Energy Use

The **metabolic rate** refers to the amount of energy an organism uses over a period of time. It is commonly measured by oxygen consumption or carbon dioxide production. Metabolic rate is **inversely proportional to body mass**, meaning smaller animals tend to have higher metabolic rates than larger animals.

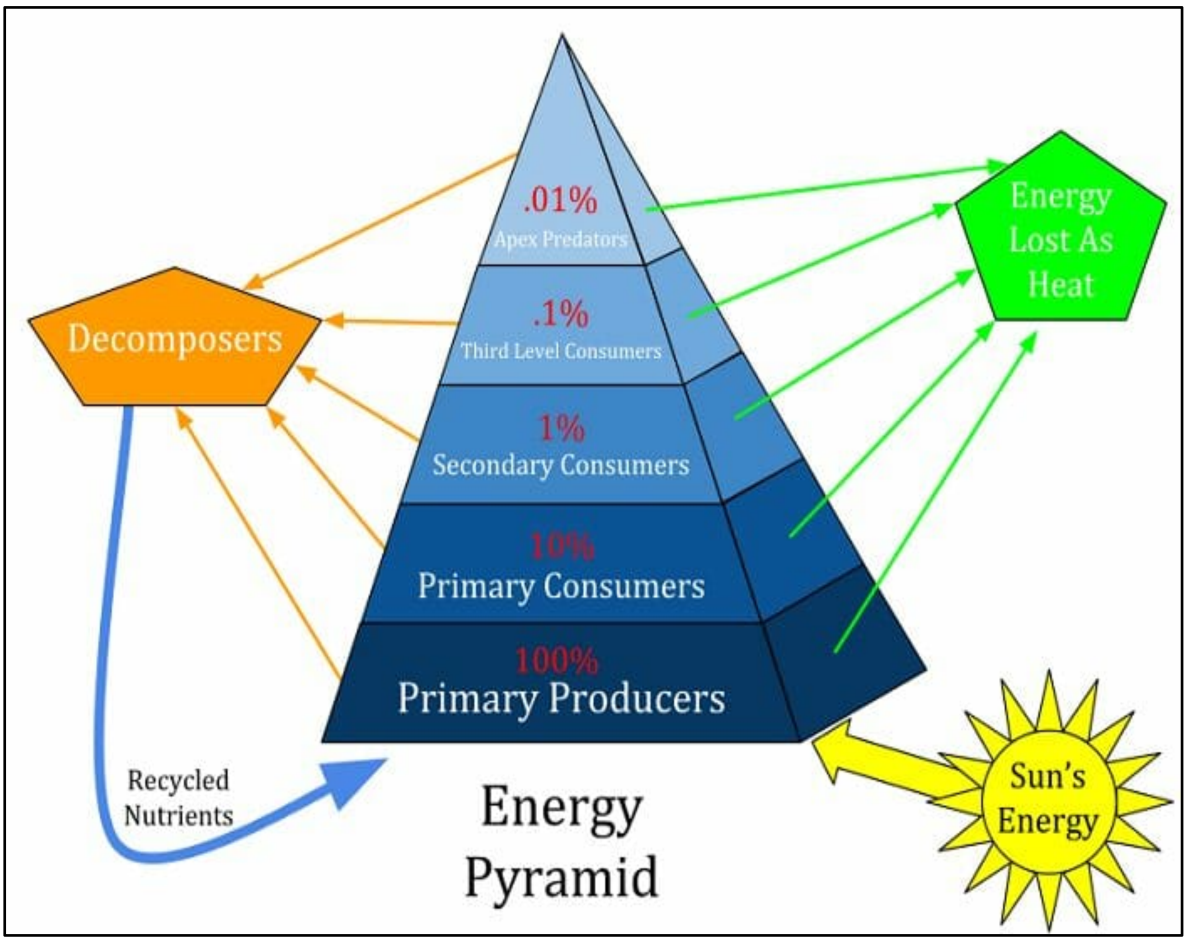
- **Endotherms** (warm-blooded animals) maintain a constant internal temperature and require more energy.
- **Ectotherms** (cold-blooded animals) rely on environmental heat sources, using less energy.



Energy Flow in Ecosystems

Energy moves through an ecosystem via **trophic levels**:

- **Primary producers (autotrophs)**: Convert sunlight into energy through photosynthesis. Some organisms are **chemosynthetic**, using chemical energy instead of sunlight.
- **Consumers (heterotrophs):**
  - **Primary consumers:** Herbivores that eat producers.
  - **Secondary consumers:** Carnivores that eat herbivores.
  - **Tertiary consumers:** Carnivores that eat other carnivores.
  - **Decomposers:** Break down dead organic material and recycle nutrients.



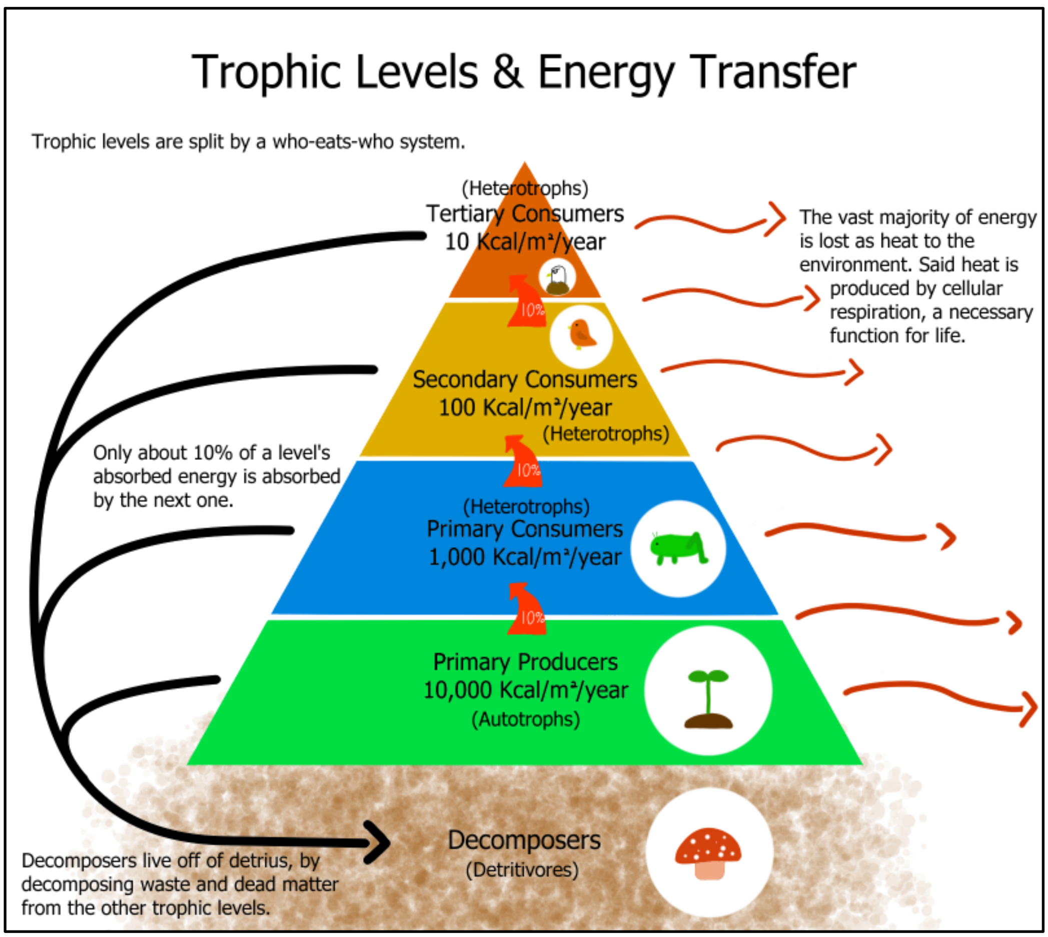
Trophic Structure and Energy Transfer

Energy transfer in ecosystems follows a **food chain**, but in reality, most ecosystems are interconnected **food webs**. Changes in the availability of energy, such as a decline in primary producers, can disrupt an entire ecosystem by affecting all higher trophic levels.

Primary Production and Energy Efficiency

Ecosystem productivity depends on the rate at which energy is converted by autotrophs:

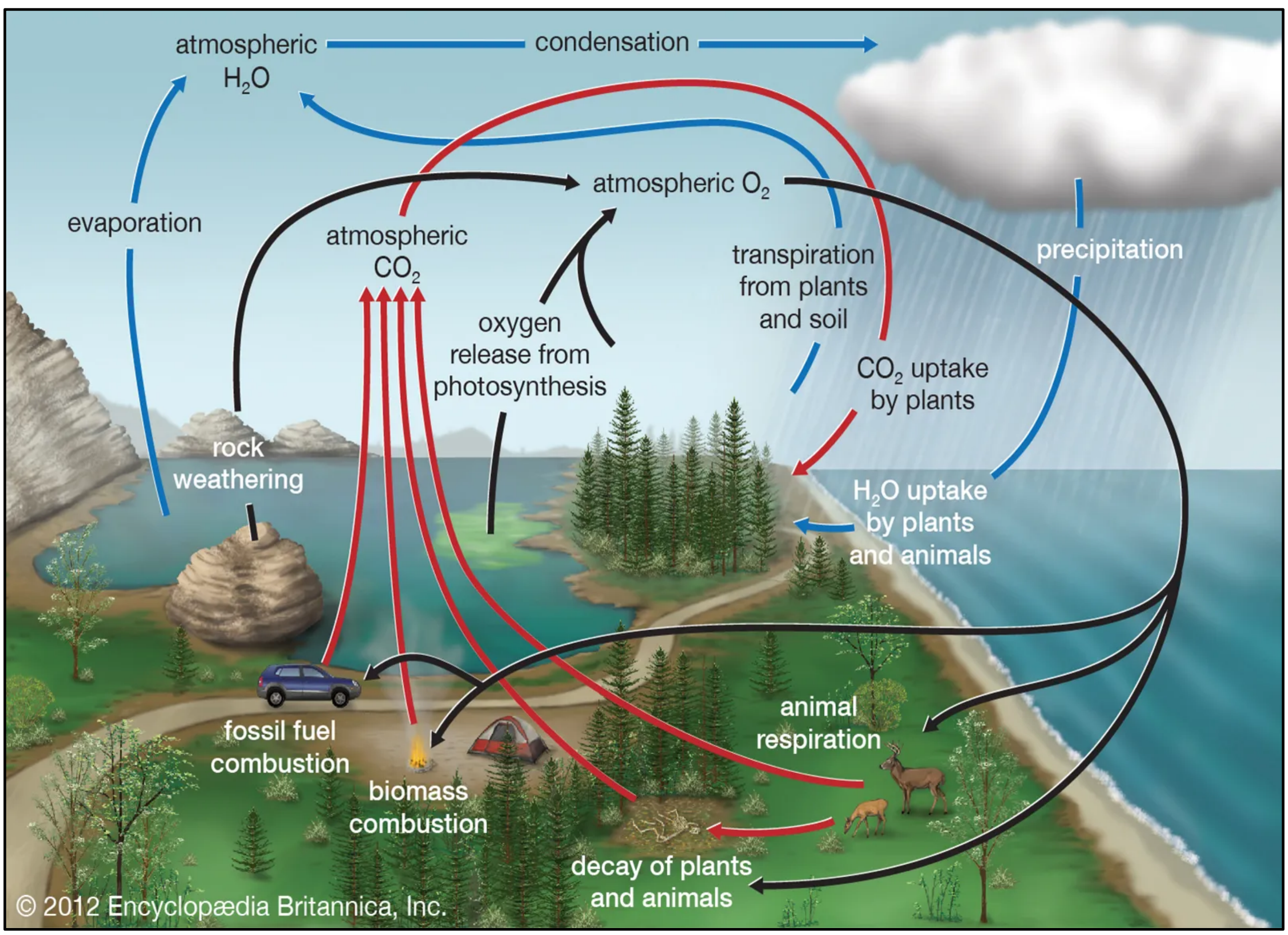
- **Gross Primary Production (GPP):** Total energy converted into chemical energy.
- **Net Primary Production (NPP):** Energy available to consumers after autotrophs use some for respiration.
- **Secondary Production:** Energy transferred to higher trophic levels.
- **Only 10% of energy** is passed between trophic levels, with most lost as heat.



Matter Cycling in Ecosystems

Unlike energy, matter cycles through ecosystems in **biogeochemical cycles**:

- **Water Cycle:** Essential for life, involving evaporation, condensation, precipitation, and groundwater flow.
- **Carbon Cycle:** Moves carbon between the atmosphere, organisms, and fossil fuels, influencing climate change.
- **Nitrogen Cycle:** Converts atmospheric nitrogen into usable forms through fixation, assimilation, and decomposition.
- **Phosphorus Cycle:** Vital for DNA and ATP, cycles through rocks, water, and living organisms.



Topic #3: Populations

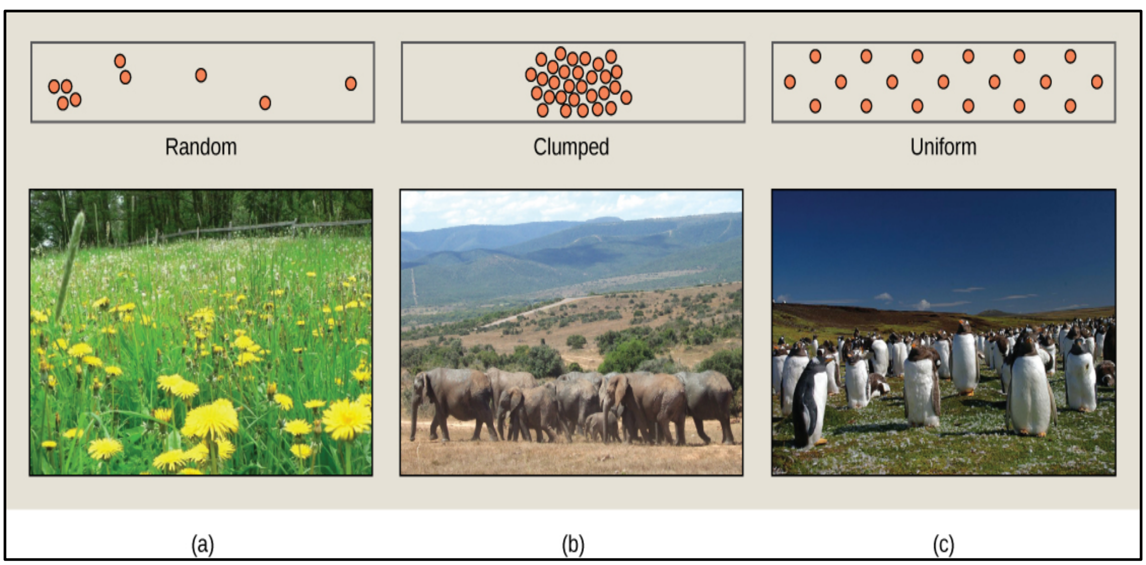
What is a Population?

A **population** is a group of individuals of the same species living in the same area. However, populations are not static—they change over time due to **births, deaths, immigration, and emigration**. The study of these changes is known as **population ecology**.

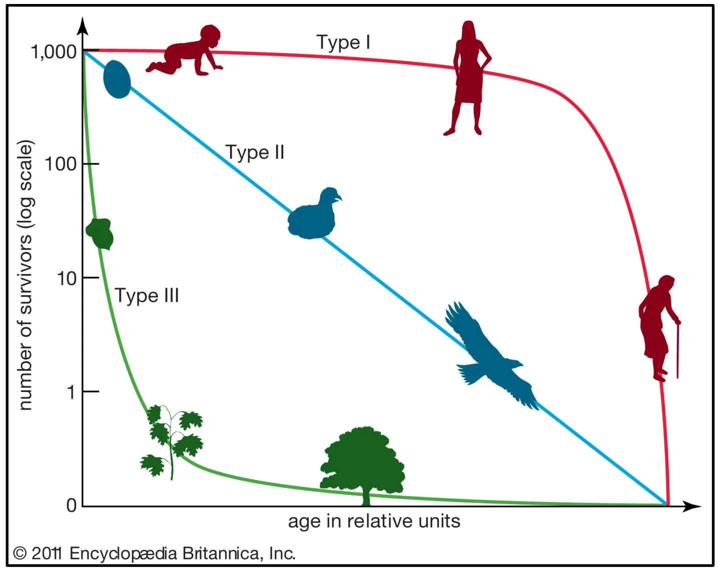
Population Density and Dispersion

Population size is influenced by its **density**, which refers to the number of individuals per unit area. Populations exhibit different patterns of **dispersion**:

- **Clumped:** Organisms gather in patches, often due to resource availability.
- **Uniform:** Evenly spaced individuals, often due to territorial behavior.
- **Random:** No predictable pattern, seen in species with wind-dispersed seeds.



Demographics and Survivorship



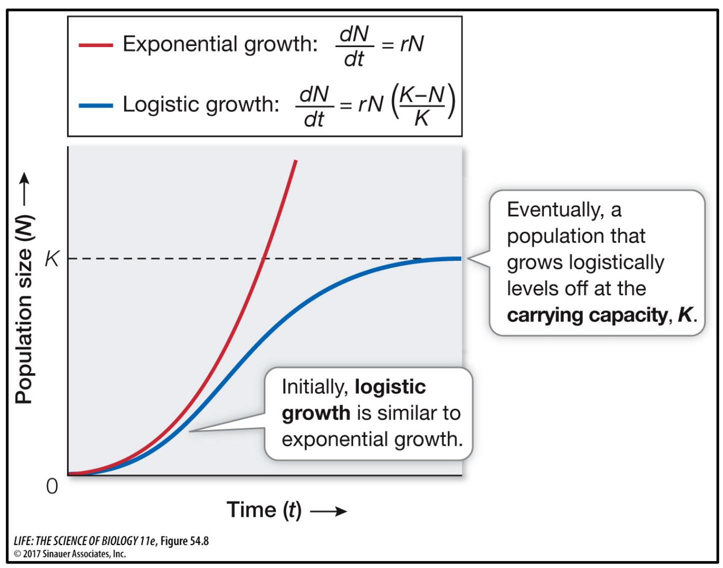
Ecologists study populations using **life tables**, which track survival patterns over time. **Survivorship curves** reveal different life strategies:

- **Type I:** High survival in early/middle life (e.g., humans, elephants).
- **Type II:** Steady mortality rate (e.g., squirrels, birds).
- **Type III:** High early mortality with few survivors (e.g., fish, plants).

Population Growth Models

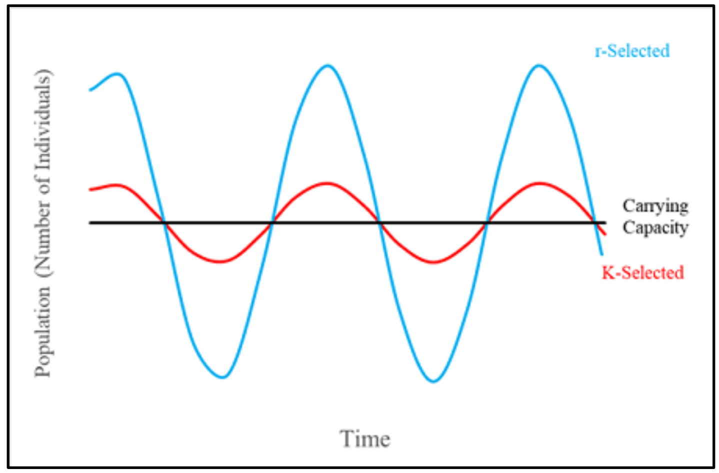
Populations grow based on birth and death rates:

- **Exponential Growth (J-curve):** Occurs in ideal conditions (easy access to food, free to reproduce, etc.).
  - The populations grow rapidly.
  - J-shaped curve.
- **Logistic Growth (S-curve):** Growth slows as populations approach carrying capacity (K).
  - Density of individuals exceeds the system's resource availability.
  - S-shaped curve.



Life History Strategies

Life history are the schedule and traits that affect an organism's schedule of reproduction and survival. They depend on (1) when reproduction begins, (2) how often the organism can reproduce, and (3) the number of offspring produced per reproductive episode. Organisms follow different reproductive strategies:



- **K-selection (density-dependent selection):** Few offspring, high parental investment (e.g., whales, trees).
  - These are sensitive to population density.
  - Seen in high density populations that are close to carrying capacity (K).
- **R-selection (density-independent selection):** Many offspring, little parental care (e.g., insects, weeds).

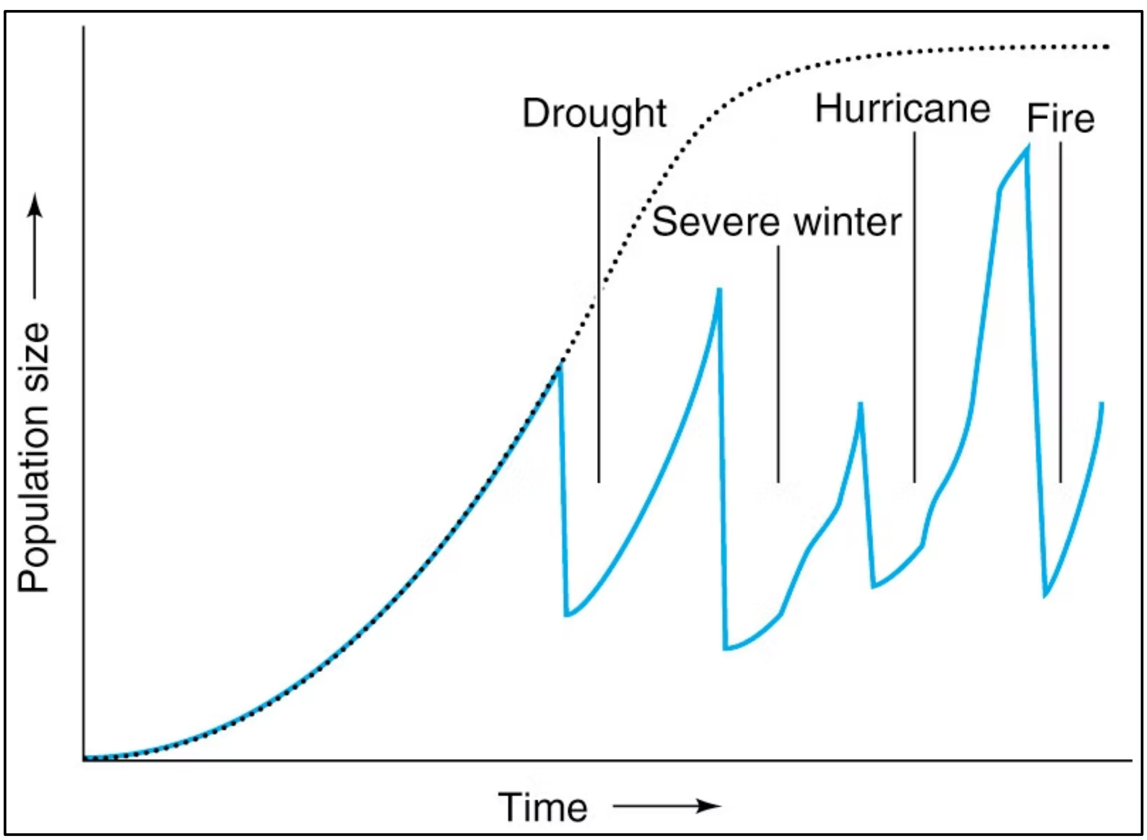
Regulation of Population Size

Density-dependent and **density-independent factors** are two types of factors that affect the size and growth of populations in an ecosystem.

1. **Density-Dependent Factors**: These are factors that have a greater effect on the population as its density (the number of individuals in a given area) increases. In other words, the impact of these factors is dependent on how crowded the population is. Some examples of density-dependent factors include:
   - **Competition for resources**: When the population is dense, resources like food, water, and shelter become limited, leading to competition among individuals.
   - **Predation**: A denser population may attract more predators, as predators find it easier to locate and capture prey.

- **Disease**: In crowded populations, diseases can spread more quickly because individuals are in close proximity to each other.
- **Parasitism**: Higher population density can lead to an increase in parasites spreading among individuals.

2. **Density-Independent Factors**: These are factors that affect the population regardless of its density. They are often environmental factors that impact populations in similar ways regardless of how large or small the population is. Examples include:
    - **Weather**: Extreme weather events like storms, droughts, or heatwaves can affect populations, regardless of their size.
    - **Natural disasters**: Events like floods, fires, or earthquakes can drastically reduce populations, regardless of their density.
    - **Human activities**: Habitat destruction, pollution, and deforestation can reduce population sizes irrespective of population density.



***Topic #4*: Community Ecology**

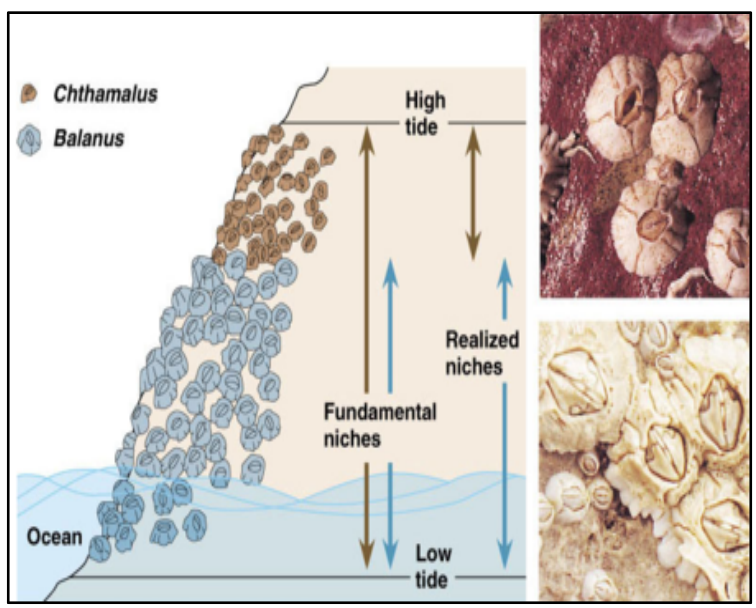
Introduction to Communities

In ecology, a **community** refers to the group of different species that coexist and interact in the same area. These species can include plants, animals, fungi, bacteria, and other organisms that share a common environment. A community is not just a random collection of species, but is defined by the relationships and interactions between them, which can significantly influence their survival and distribution.

The Concept of Niche

Each species within a community has a specific role or **niche**. A niche goes beyond simply describing where an organism lives (its habitat); it also includes the full range of conditions and resources that a species needs to survive, reproduce, and thrive. The niche can be broken down into different components. The **habitat** is the physical location where an organism lives, while the **ecological niche** refers to the role a species plays within that habitat, including its interactions with other species and its use of resources.

There are two important aspects of a species' niche: the **fundamental niche** and the **realized niche**. The **fundamental niche** is the potential range of conditions a species can tolerate and the resources it could theoretically use in the absence of competition or other limiting factors. However, due to interactions with other species, a species often occupies a **realized niche**, which is the actual set of conditions and resources it uses after

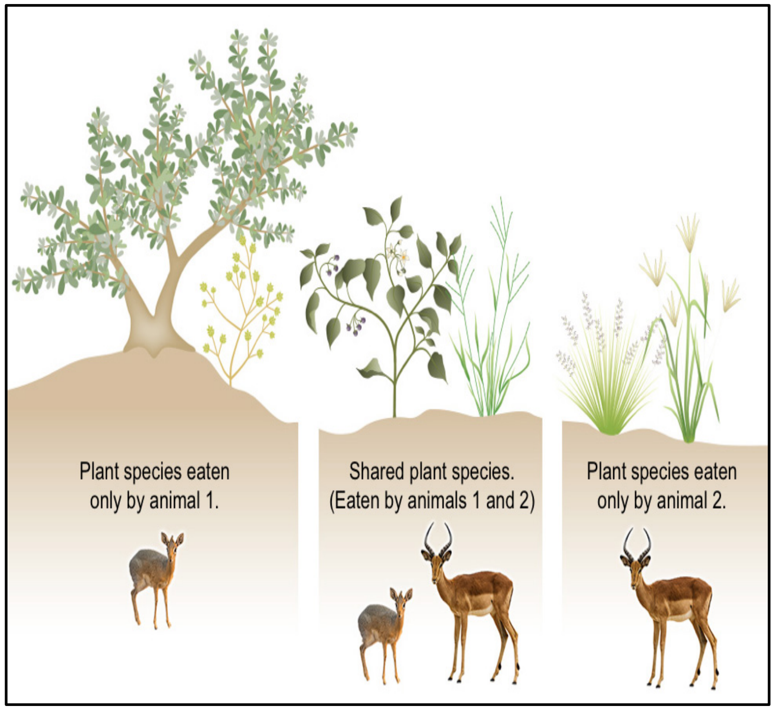


considering ecological pressures such as competition, predation, and disease.

Interspecific Interactions

Competition

One of the most significant types of interspecific interaction is **competition**, which occurs when two species vie for the same resources, such as food, space, or light. The **competitive exclusion principle** states that two species that occupy the same niche cannot coexist indefinitely if resources are limited, as one will eventually outcompete the other. However, species may engage in **niche partitioning**, which is the division of resources to minimize direct competition. Through niche partitioning, species can coexist by utilizing different resources or utilizing them at different times or in different ways.

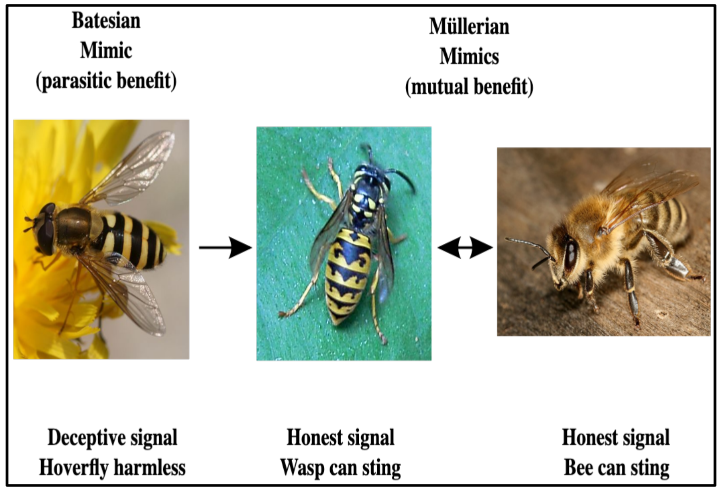


Predation

The interaction where one species (the predator) hunts and consumes another (the prey) is referred to as **predation**. This relationship often drives the evolution of defensive traits in prey species.

- For example, many prey species have evolved **cryptic coloration**, allowing them to blend into their surroundings and avoid detection by predators.

- Some species also use **Batesian mimicry**, in which a harmless species resembles a dangerous or poisonous species to deter predators.
- On the other hand, **Müllerian mimicry** occurs when two harmful or poisonous species evolve to resemble each other, reinforcing predator avoidance.

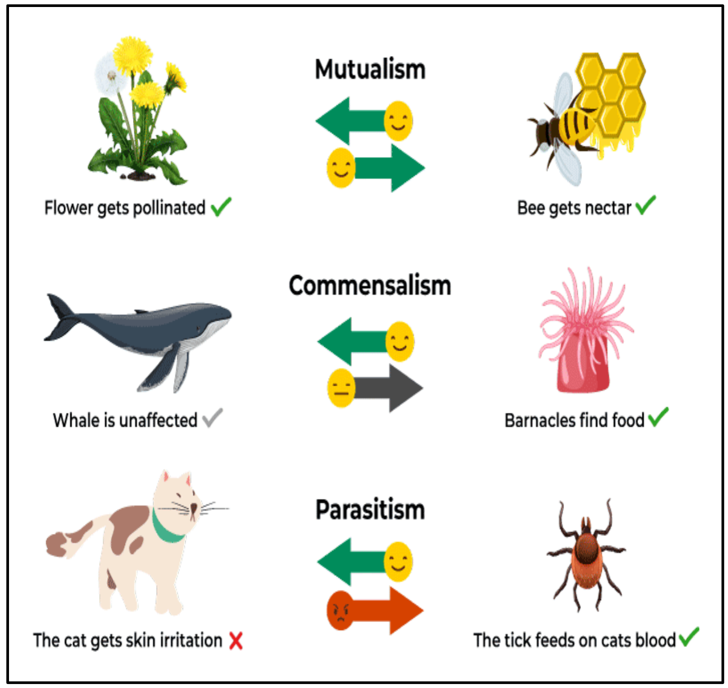


Herbivory

A specific type of predation is **herbivory**, where herbivores feed on plants. This interaction can influence the structure of plant communities and drive evolutionary changes in both plants and herbivores. For example, plants may evolve physical defenses like thorns or produce chemical toxins to deter herbivores, while herbivores might develop mechanisms to counter these defenses.

Symbiotic Relationships

In addition to competitive and predatory interactions, species within a community can form **symbiotic relationships**, in which two or more species live together in close association. There are different types of symbiotic interactions, including **parasitism**, **mutualism**, **commensalism**, and **facilitation**.



- **Parasitism**: In parasitism, one species benefits at the expense of another, typically weakening or harming the host species.
- **Mutualism**: In mutualism, both species benefit from the interaction. For example, bees pollinate flowers while obtaining nectar, benefiting both species.
- **Commensalism**: This occurs when one species benefits from the relationship while the other is unaffected. An example of this could be birds that feed on insects stirred up by grazing herbivores.
- **Facilitation**: Facilitation happens when one species benefits another without being directly harmed or benefited itself, such as when certain plants improve soil conditions for others.

***Topic #5*: Biodiversity and Disturbances to Ecosystems**

Species Diversity and Ecological Disturbances

Species Diversity:

Species diversity refers to the variety and abundance of different species within a given ecosystem or community. It is an important measure of ecosystem health, as diverse ecosystems are typically more resilient to changes and disturbances. Species diversity is often quantified using indices such as Simpson's Diversity Index.

Simpson's Diversity Index:

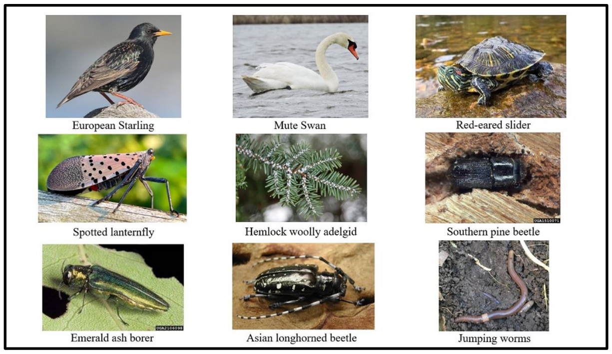
The **Simpson's Diversity Index (D)** is a mathematical formula used to measure the diversity of a community. It takes into account both the number of species and the relative abundance of each species. The equation is:

$$D_s = 1 - \sum \left(\frac{n}{N}\right)^2$$

D_s = Diversity Index
n = Number of individuals for each species
N = Total number of all individuals

- **High Diversity Index**: A high value (closer to 1) indicates a diverse community, where species are evenly distributed and no single species dominates.
- **Low Diversity Index**: A low value (closer to 0) indicates low diversity, where one or a few species dominate the ecosystem, which can reduce ecosystem resilience and function.

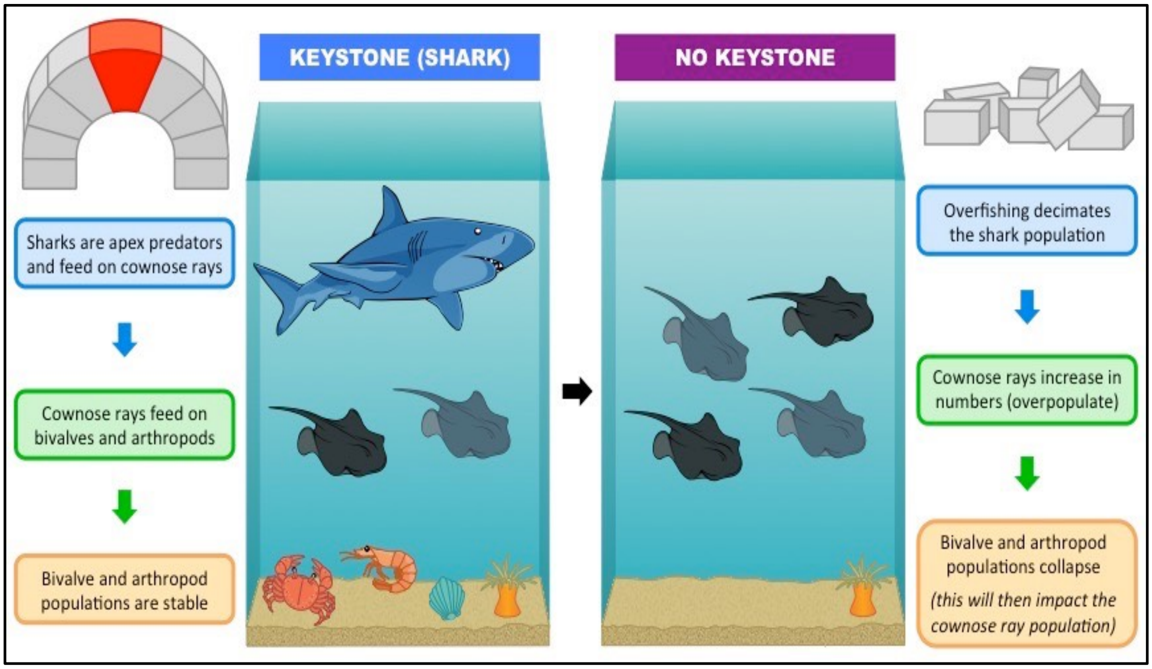
Invasive Species:



Invasive species are non-native species that are introduced to an ecosystem and cause harm by outcompeting native species for resources, altering habitat structures, and disrupting ecological processes. They can significantly reduce species diversity and negatively impact ecosystem stability. Examples of invasive species include the **zebra mussel** in North America, which disrupts aquatic ecosystems, and the **European starling**, which competes with native bird species for nesting sites.

Keystone Species:

A **keystone species** is one whose presence and role within an ecosystem have a disproportionately large effect on the structure and diversity of that ecosystem. Removing a keystone species can cause dramatic changes in the ecosystem, potentially leading to a collapse in biodiversity.



- **Examples**:
  - **Sea otters**: In kelp forest ecosystems, sea otters regulate sea urchin populations, preventing them from overgrazing on kelp and maintaining biodiversity.
  - **Gray wolves**: In Yellowstone National Park, wolves control the population of herbivores like elk, which allows vegetation to thrive and supports a variety of other species.

- **Importance**: Keystone species maintain the balance of ecosystems and prevent any one species from becoming overly dominant, thus helping to maintain species diversity.

Disturbances:

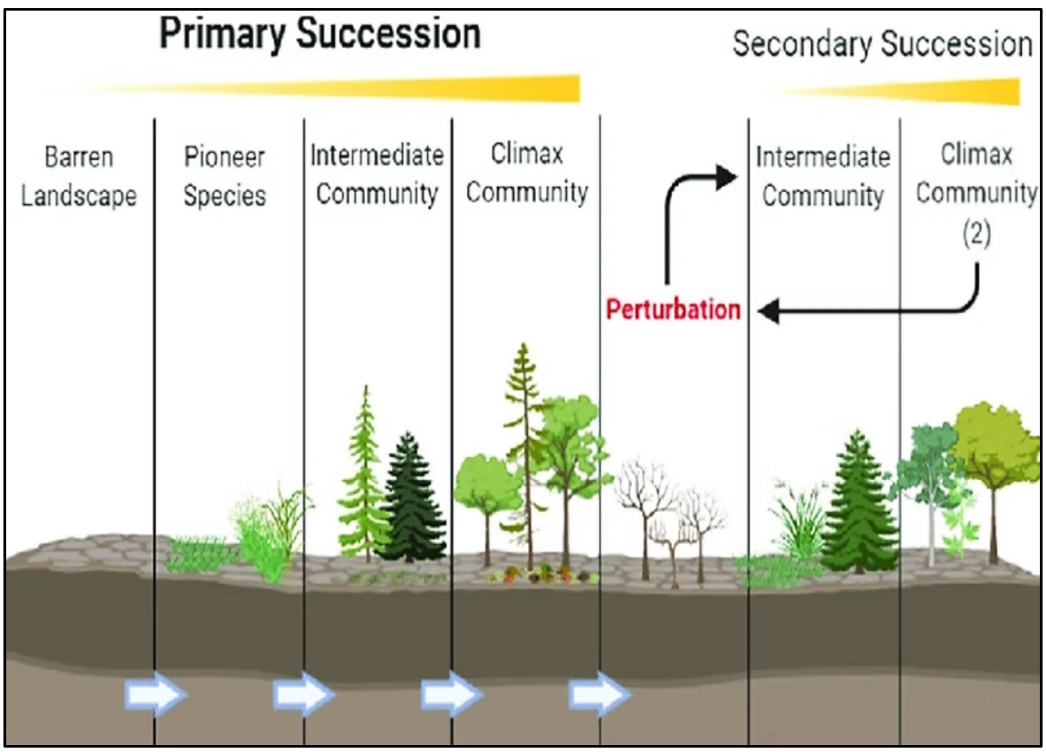
Ecological disturbances are events or processes that disrupt the structure of an ecosystem, often altering resource availability, species composition, or habitat. Disturbances can be natural or human-induced and can vary in scale and intensity.

- **Examples**:
  - Natural disturbances: Wildfires, hurricanes, floods, volcanic eruptions, and droughts.
  - Human-induced disturbances: Habitat destruction, pollution, deforestation, and urbanization.

Ecological Succession:

Ecological succession is the process by which ecosystems change and develop over time following a disturbance. It involves the gradual replacement of species in a community, leading to the establishment of a more stable and mature ecosystem.

- **Primary Succession**: Occurs in areas where no soil or life previously existed, such as after a volcanic eruption or glacier retreat. It starts with pioneer species like lichens and mosses and eventually leads to a mature ecosystem.
- **Secondary Succession**: Occurs in areas where a disturbance has disrupted an existing ecosystem but soil and some organisms remain, such as after a forest fire or abandoned agricultural land. This process is faster than primary succession due to the presence of soil and nutrients.



Human Disturbances:

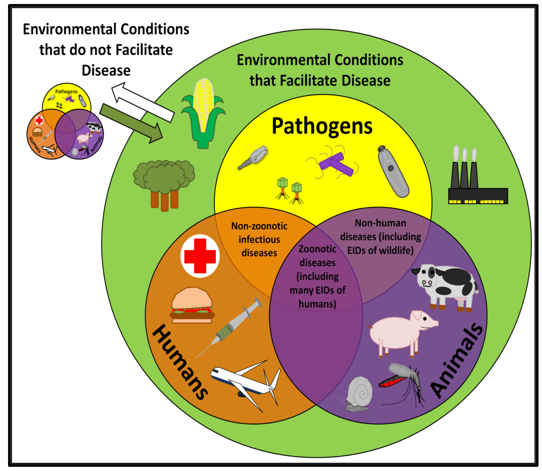
Human activities, including deforestation, agriculture, pollution, and urbanization, are major causes of ecological disturbance and biodiversity loss. These disturbances can alter habitats, introduce invasive species, and disrupt natural processes, leading to the decline of native species.

Threats to Biodiversity:

Several factors threaten biodiversity and the health of ecosystems:

- **Habitat Loss**: Destruction or fragmentation of natural habitats due to human activities (e.g., urbanization, agriculture) is one of the leading causes of biodiversity loss. When habitats are destroyed or fragmented, species lose their homes and are unable to survive.
- **Invasive Species**: Non-native species that invade ecosystems often outcompete or prey on native species, leading to declines in native populations and ecosystem imbalances.
- **Overharvesting**: The excessive harvesting of natural resources, such as logging, fishing, or hunting, can deplete species populations and disrupt ecological balance.
- **Global Change**: Climate change, altered weather patterns, and other global environmental changes can threaten species and ecosystems by affecting temperature, rainfall, and resource availability.

Effects on Endangered Species:



The loss of biodiversity, habitat destruction, and other disturbances have significant effects on endangered species. As their habitats shrink or degrade, these species face greater challenges in finding food, mates, and shelter, which can lead to their extinction. Many endangered species are also vulnerable to changes in climate and invasive species that disrupt their ecosystems.

Biogeographical Factors:

The distribution of species across the globe is influenced by various biogeographical factors, including:

- **Latitude**: Species diversity tends to increase as one approaches the equator, with tropical regions generally having higher biodiversity than temperate or polar regions.
- **Area**: Larger areas tend to support more species, as they provide more habitats and resources. Island ecosystems, for example, often have fewer species than continental areas due to their limited space and isolation.
- **Pathogens**: The spread of diseases and pathogens can drastically affect species populations, especially when species lack immunity or are in stressed environments due to other factors.