3. Consider the following two ecosystems located at the same latitude, and choose the best description.

Ecosystem A	Ecosystem B
266 sunny days/year	183 sunny days/year
282 frost-free days/year	125 frost-free days/year
25" rain/year	36" rain/year

(A) Ecosystem A would be expected to have less species diversity because it has abundant light and a long growing season.
(B) Ecosystem B would have greater species diversity because it receives more water annually.
(C) Ecosystem A would be expected to have the highest gross primary productivity because it has more sunny days and a longer growing season.
(D) Ecosystem B would be expected to have the highest net primary productivity because it has longer days, allowing time for more photosynthesis.

BIG IDEA 4: Laboratory 11, Transpiration

Overview of the Lab

Transpiration is the major mechanism that drives the movement of water through a plant. In the first section of the laboratory, you will calculate leaf surface area and use this measurement to determine the average number of stomata per square millimeter of leaf. The investigation then focuses on learning a technique to measure the rate of transpiration, such as using a potometer or the whole-plant method. This knowledge will enable you to design an experiment to answer a question about a factor that influences the rate of transpiration.

YOU MUST KNOW

- The function of stomata in gas exchange in plants. What enters? What leaves?
- The role of water potential and transpiration in the movement of water from roots to leaves.
- The effects of various environmental conditions on the rate of transpiration.

SCIENCE PRACTICES: CAN YOU . . .

- Predict and justify whether a plant cell will give or lose water based on water potential?
- Create and annotate a diagram to show what would happen to grass planted near a road that has been salted in winter, including water potential in your representation?

Hints and Review

- Review **hydrogen bonding** (see Topic 1, Chapter 3)! In water, a hydrogen bond is a weak bond between the hydrogen of one water molecule and the oxygen of another, and it accounts for the unique properties of water, including adhesion and cohesion.
- Water enters a plant through the root hairs, passes through the tissues of the root into the xylem, and travels up through the xylem vessels into the leaves.
- **Transpiration** is the evaporation of water from the leaves through the stomata. It is the major force that pulls the water up through the plant.
- Study Figure 11.1 to see this process. When water enters the roots, hydrogen bonds link each water molecule to the next one (*cohesion*), so the molecules of water are pulled up the thin xylem vessels like beads on a string. The water molecules also cling to the thin walls of the xylem cells (*adhesion*). The water moves up the plant, enters the leaves, moves into air spaces in the leaf, and then evaporates (transpires) through the *stomata* (singular, *stoma*).

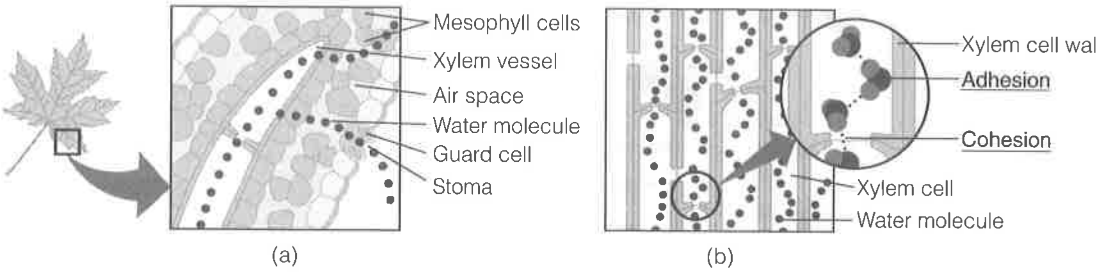
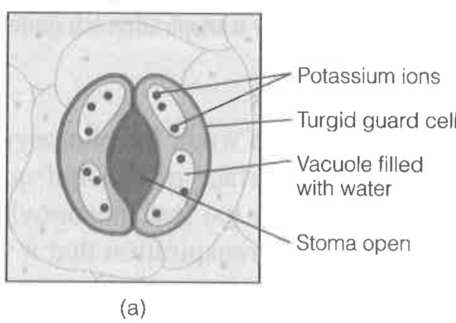
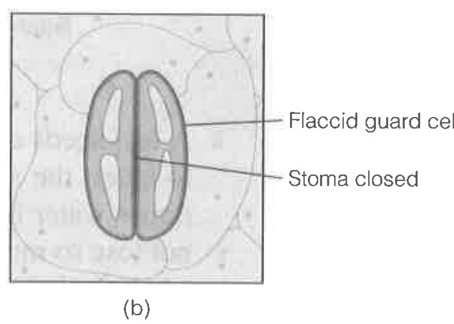


Figure 11.1 Leaf anatomy showing movement of water molecules

- **Stomata** are the pores in the epidermis of a leaf. There are hundreds of stomata in the epidermis of a leaf, mostly located in the lower epidermis. This reduces water loss because the lower surface receives less solar radiation than the upper surface. Each stoma allows the carbon dioxide necessary for photosynthesis to enter, while water evaporates through each one in transpiration.
- **Guard cells** are cells surrounding each stoma. They help regulate the rate of transpiration by opening and closing the stomata. To understand how they function, study the following figures. As you look at the figures, keep in mind that an increase in solute concentration lowers the water potential of the solution and that water moves from a region with higher water potential to a region of lower water potential.
- Notice that in Figure 11.2a the guard cells are turgid, or swollen, and the stomatal opening is large. This turgidity is caused by the accumulation of K^+ (potassium ions) in the guard cells. As K^+ levels increase in the guard cells, the water potential of the guard cells drops, and water enters the guard cells.



11.2a Open Stomata



11.2b Closed Stomata

- In Figure 11.2b, the guard cells have lost water, which causes the cells to become flaccid and the stomatal opening to close. This may occur when the plant has lost an excessive amount of water. In addition, it generally occurs daily as light levels drop and the use of CO_2 in photosynthesis decreases.

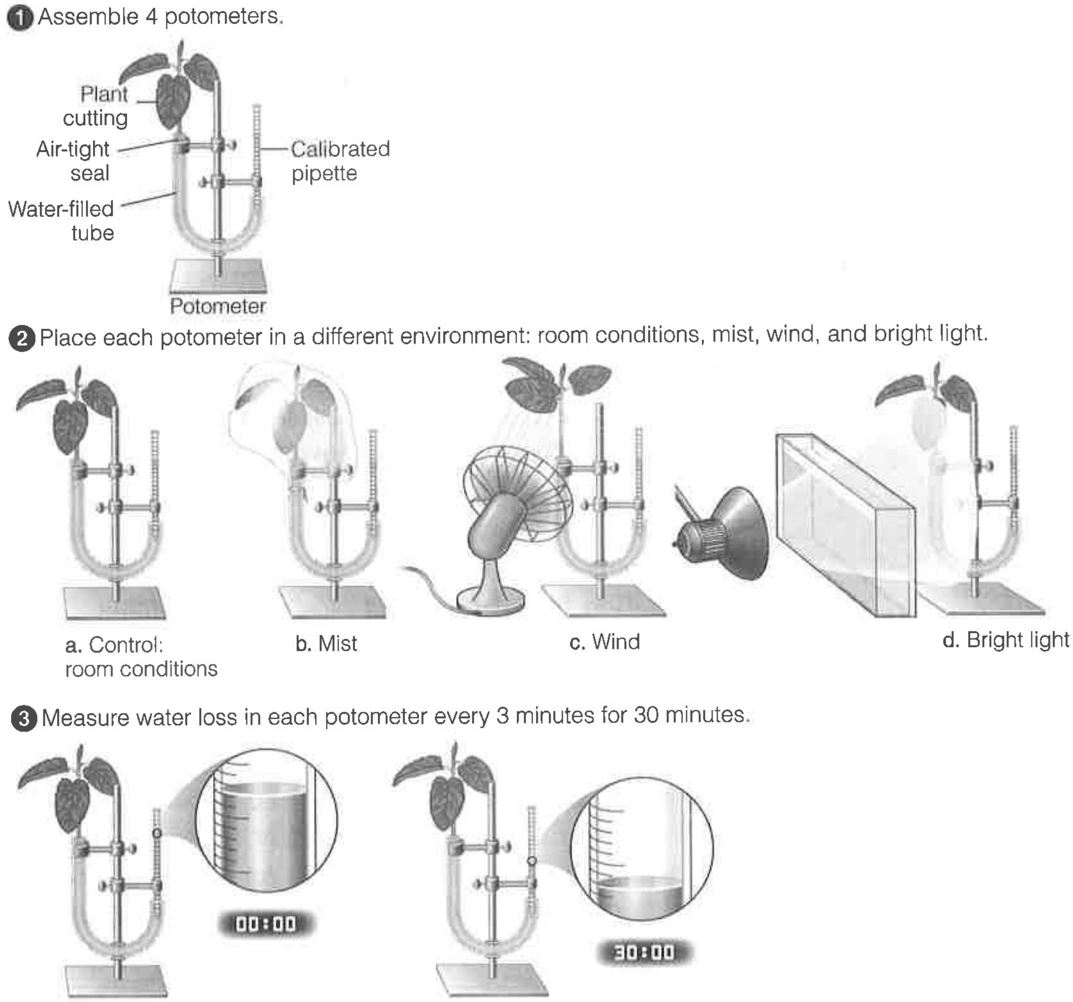


Figure 11.3 Procedure for transpiration lab (potometer method)

- A leaf needs carbon dioxide and water for photosynthesis. For carbon dioxide to enter, the stomata on the surface of the leaf must be open. Transpiration draws water from the roots into the leaf mesophyll. However, the plant must not lose so much water during transpiration that it wilts. The plant must strike a balance between conserving water and bringing in sufficient amounts of CO_2 for photosynthesis.
- One way to measure water loss from a plant is to use a *potometer*, a device that measures the rate at which a plant draws up water. Because the plant draws up water as it loses it by transpiration, you are able to measure the rate of transpiration. The basic elements of a potometer are shown in Figure 11.3, step 1. They are
  - a plant cutting,
  - a calibrated pipette to measure water loss,
  - a length of clear plastic tubing, and
  - an airtight seal between the plant and the water-filled tubing.

PRACTICE THE PRACTICE: Engage in Scientific Questioning

Figure 11.3 shows a typical setup to investigate a variety of environmental effects on the rate of transpiration. Based on your knowledge of transpiration developed in this investigation, can you answer the following questions? (The answers are below on this page.)

1. What are some factors that you would need to hold constant for a valid *control*?
2. Predict the rate of transpiration in the plant that has been misted and placed in a plastic bag, compared with the control, and justify your prediction.
3. Predict the rate of transpiration in the plant in front of the fan, compared with the control, and justify your prediction.
4. Predict the rate of transpiration in bright light, compared with the control, and justify your prediction.
5. Why is the bright light being shone through a tub filled with water?

Questions

1. All of the following enhance water transport in terrestrial plants EXCEPT
   (A) hydrogen bonds linking water molecules.
   (B) capillary action due to adhesion of water molecules to the walls of xylem.
   (C) evaporation of water from the leaves.
   (D) K^+ being transported out of the guard cells.

2. Under conditions of bright light, in which part of a transpiring plant would water potential be lowest?
   (A) xylem vessels in the leaves
   (B) xylem vessels in the roots
   (C) root hairs
   (D) the spongy mesophyll of the leaves

Answers to PRACTICE THE PRACTICE: Engage in Scientific Questioning, above

1. In order for the *control* to be valid, you should consider using the same type of plant, have the same relative amount of leaf surface, have the water in all potometers at the same temperature, and place the control and experimental plant cuttings in virtually identical conditions with the exception of the single factor you are testing.
2. The plant cutting inside the plastic bag is in a situation of *high humidity*. Because of high water potential in the area surrounding the leaves, the rate of transpiration will be low.
3. The potometer with the *fan* shows increased water loss compared with the control. The reason is that the air movement results in greater evaporation, lowering water potential outside the plant surface, resulting in a higher rate of water loss or transpiration.
4. The potometer in *bright light* generally shows a higher rate of water loss, indicating more photosynthesis than the control.
5. A bright light produces heat, which operates as another variable. The water-filled container is a heat sink and will minimize the effect of heat on the plant.

BIG IDEA 4: Investigation 12, Fruit Fly Behavior

Overview of the Lab

- In this lab you will explore behaviors in an invertebrate and design an experiment to answer a question about behavior. Animals exhibit a variety of behaviors, both learned and innate, that promote their survival and reproductive success in a variety of ways. In this investigation, you will make detailed observations of an organism's behavior and design a controlled experiment to test a hypothesis about a specific case of animal behavior.
- If you use the 2012 "AP Investigations" manual, your experimental organisms may be fruit flies (as in the title of the investigation). It is equally possible that your teacher may select another species to use, such as mealworms or pill bugs.

YOU MUST KNOW

- Behaviors are regulated by various mechanisms and are acted on by natural selection.
- Descriptions of various animal behaviors, such as orientation behavior, geotaxis, phototaxis, chemotaxis, and how the behavior is adaptive.

SCIENCE PRACTICES: CAN YOU . . .

- Design a plan for collecting data to show how a particular species is affected by biotic or abiotic interactions?
- Analyze data collected to identify possible patterns and relationships between an organism or species and a biotic or an abiotic factor?
- Apply mathematical routines, such as statistical analysis, to evaluate data?

Hints and Review

- In this lab you will make detailed observations and learn about some interesting animal behaviors. Because the topic is so broad and there are so many local organisms and possibilities for your teacher to choose from, we will only make a few comments about animal behavior. This lab presents a wonderful opportunity to teach experimental design, so this is where we focus our discussion.

- Refer to the Introduction of this book for hints about writing the lab essay. At the conclusion of this course, you should have conducted a number of investigations where you have asked your own question and developed a procedure to investigate your hypothesis. You should now be able to design a controlled experiment to test a single variable, record data in a logical manner, and present your conclusions.
- There are hundreds of species of fruit flies—so how do members of the same species find each other and signal willingness to mate? Each species has evolved a complex series of behaviors that appear to be genetically programmed. Students who do Lab 11 in the 2001 AP Biology Lab Manual investigate this behavior in *Drosophila melanogaster.*
- How do fruit flies find their food sources? orient to gravity? orient to light? Investigation 12 (Fruit Fly Behavior) encourages a look at a number of behaviors in fruit flies and directs you in the preparation of a choice chamber.
- A common behavior experiment involves observing how pill bugs respond to their environment. In this experiment, students place pill bugs in a choice chamber—half in the side lined with dry filter paper and the other half in the side lined with wet filter paper. Pill bugs are crustaceans, so they respire through gills and generally live in a moist habitat. Because of this, most students hypothesize that more pill bugs will be found in the moist chamber. This is often what occurs but not always!
- This brings us to an important consideration: If a student prepares a single-choice chamber, the exercise is not a controlled experiment. Could there be more light at one end of the choice chamber? more activity and vibration? a chemical residue on one side? Any of these conditions and more could possibly influence the organism's behavior. Without a control, it is very risky to state a conclusion. What's needed is a **controlled experiment**.

TIP FROM THE READERS

Even if you did not do this investigation, we recommend you carefully study the suggestions about experimental design found in the following box. It reviews practices followed all year long and applies to virtually any inquiry lab you might do!

PRACTICE THE PRACTICE: Experimental Design: Plan and Implement Data Collection Strategies

- A controlled experiment begins with a ***hypothesis***—a proposed solution for the problem being investigated. A hypothesis is often written as an IF, THEN statement that predicts the outcome we might expect if our data supports the hypothesis. A hypothesis should not only predict results but must also be testable.
- In a controlled experiment, *all variables are held constant,* except the one being tested or manipulated. For instance, if the goal is to test response to wet versus dry conditions, the light, temperature, chemicals in the filter paper or on the dish surface, and movement of the table must all remain constant. In addition, all the experimental organisms must be of the same approximate age, size, and state of health. It is not enough to say that you will hold all variables constant; you must be explicit in your explanation of how you will do this.
- To be meaningful, the experiment must include a *large sample size* to be representative of a general condition.
- The *results must be measurable!* Are you going to count, measure, or find the mass? You must devise some way to quantify the results.
- Several *repetitions (or replicates)* of the experiment must be done. Like a large sample size, having several repetitions lets you verify your result.
- Before you design an experiment, it may be useful to *search the literature* to learn what has already been done and to help develop ideas for a reasonable study.
- Finally, *statistical analysis of your data* (such as the Chi-square test at the end of this topic) should be done to validate experimental results.

Questions

1. A student wanted to study the effect of nitrogen fertilizer on plant growth, so she took two similar plants and set them on a windowsill for a two-week observation period. She watered each plant the same amount, but she gave one a small dose of fertilizer with each watering. She collected data by counting the total number of new leaves on each plant and measuring the height of each plant in centimeters. Which of the following is a significant flaw in this experimental setup?
   (A) There is no variable factor.
   (B) There is no control.
   (C) There is no repetition.
   (D) Measurable results cannot be expected.

2. Students placed five pill bugs on the dry side of a choice chamber and five pill bugs on the wet side. The students collected data on the number on each side every 30 seconds for 10 minutes. After 6 minutes, eight or nine pill bugs were continually on the wet side of the chamber, and several were under the filter paper. Which of the following is *not* a reasonable conclusion from these results?
   (A) It takes the pill bugs several minutes to explore their surroundings and select a preferred habitat.
   (B) Pill bugs prefer a moist environment.
   (C) Pill bugs may find chemicals in dry filter paper irritating.
   (D) Pill bugs demonstrate no significant habitat preference.

3. If a student wanted to determine whether pill bugs prefer a moist or a dry environment, what would be a good first step in looking at the data?
   (A) Total the number of pill bugs on the dry side throughout the entire experiment and compare this with the number on the wet side throughout the experiment.
   (B) After waiting 5 minutes for the pill bugs to acclimate, count the number of pill bugs on the dry side every 30 seconds for 5 minutes and determine the total number on the dry side. Do the same for the wet side, and compare the data.
   (C) Compare the number of pill bugs on the dry side at the end of 10 minutes with the number of pill bugs on the wet side at the end of 10 minutes.
   (D) Divide the number of pill bugs on the dry side throughout the experiment by the number on the wet side throughout the experiment.

4. Which of the following hypotheses is stated best?
   (A) If pill bugs are allowed free movement, then more will be found in a moist environment than in a dry environment.
   (B) If pill bugs like a moist environment, then they will move to the wet side of a choice chamber.
   (C) If an experiment with pill bugs is run for 10 minutes, then more pill bugs will be found in the most favorable environment.
   (D) Pill bugs are found in moist habitats, so I predict that more will be found where it is wet.

BIG IDEA 4: Investigation 13, Enzyme Activity

Overview of the Lab

- This experiment investigates the enzymatic activity of peroxidase. In Procedure 1, you will learn how to measure the activity of peroxidase; in Procedure 2, you will investigate the effect of varying pH on enzyme activity. The investigation then requires the design of an experiment to determine the effect of a selected variable on enzyme activity.
- Your teacher might choose to use another enzyme-substrate system, so the tips that follow will be generalized for any enzyme.

YOU MUST KNOW

- Enzymes are proteins, so their final conformation is affected by the interactions between their R-groups.
- The shape of an enzyme and its active site determine its activity.
- How factors such as temperature, pH, and enzyme concentration affect the rate of an enzyme reaction.

SCIENCE PRACTICES: CAN YOU . . .

- Design a controlled experiment to measure the activity of a specific enzyme under varying conditions?
- Use mathematical routines to calculate the rate of a reaction from a graph or data chart?
- Predict and justify how changing an environmental factor such as temperature or pH would alter an enzyme's activity?

Hints and Review

- Enzymes are large globular proteins. Much of their three-dimensional shape is the result of interactions between the R (variable) groups of their amino acids. Anything that changes these interactions will change the shape of the enzyme and therefore alter the rate of reaction. The *active site* is the portion of the enzyme that will interact with the substrate.
- Remember: *Change the shape, change the function!*
- Enzyme activity is affected by pH and temperature because these variables affect the 3-D shape of the enzyme. Extremes of pH and temperature result in *denaturation*, when the 3-D shape is so altered that the enzyme can no longer function.
- Enzymes are not denatured by cold, but the rate of reaction is decreased as temperature decreases.

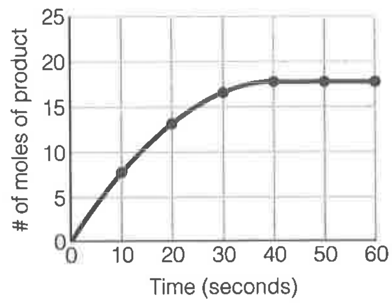


Figure 13.1 Enzyme activity over time

Enzyme Action Over Time

We can calculate the rate of an enzymatic reaction by measuring, over time, either the disappearance of substrate (as in our catalase example) or the appearance of product (as in Figure 13.1). For example, on the graph, what is the rate, in moles per second, over the interval from 0 to 10 seconds?

$$\text{Rate} = \frac{\Delta y}{\Delta x}$$

For this example, the rate would be

$$\frac{7 \text{ moles} - 0 \text{ moles}}{(10 \text{ seconds} - 0 \text{ seconds})} = \frac{7}{10}$$
$$= 0.7 \text{ moles/second}$$

- Note that the slope of the graph is steepest during the *initial* time period; this is when the rate of a reaction is greatest and occurs because the substrate is most abundant, allowing for more enzyme–substrate collisions. The rate of the reaction decreases as substrate is consumed and the slope of the graph flattens.
- What is the rate for this same reaction between 40 and 60 seconds? (It is 0.) You should be able to explain this.

Questions

1. In order to keep the rate of reaction constant over the entire time course, which of the following should you do?
   (A) Add more enzyme.
   (B) Gradually increase the temperature after 60 seconds.
   (C) Add more substrate.
   (D) Add H_2SO_4 after 60 seconds.

2. To determine the rate of enzyme activity, you do an experiment in which you mix enzyme and substrate together for 30 seconds, 60 seconds, 90 seconds, and 120 seconds. After the specified times, you add H_2SO_4 (sulfuric acid) to the reaction chamber to halt the reaction. What is the role of H_2SO_4 in this experiment?
   (A) It is the substrate on which the enzyme acts.
   (B) It denatures the enzyme by altering the active site.
   (C) It accelerates the reaction between enzyme and substrate.
   (D) It blocks the active site of the enzyme.

Statistical Analysis: Chi-Square Analysis of Data

Overview of Chi-Square

It is not sufficient to say, "My data looks really good!" or "The results were very close to what I expected." In science, we impose rigorous tests to support the validity of results. One of these tests is Chi-square analysis. Here is a short review of how to do this test and at the same time check your knowledge of genetic ratios expected with different crosses.

YOU MUST KNOW

- What is meant by "degrees of freedom," "critical value," "probability value," and "null hypothesis".
- How to do Chi-square analysis of data and explain your results.

Chi-Square Analysis of Data

Red-eyed fruit flies mate and produce the offspring shown on the right hand side of the following table. What was the genetic make-up of these red-eyed flies? **Explain** your conclusion. (Remember, this means you are to provide a *claim*, *evidence*, and *reasoning*.)

F_1 RESULTS	OBSERVED PHENOTYPE AND NUMBERS
	Red eyes
♂ MALES	12
♀ FEMALES	8

(a)

F_2 RESULTS	OBSERVED PHENOTYPE AND NUMBERS	
	Red eyes	Sepia eyes
♂ MALES	19	4
♀ FEMALES	12	9

(b)

Figure 1 Data table of *Drosophila* (1)

- From the data presented, you can deduce that the F_1 cross was between individuals heterozygous for eye color: $se^+ se$ X $se^+ se$ (se^+ = red eyes, se = sepia) because this is the only cross that would yield offspring with a 3:1 distribution of red to sepia eyes. So your *CLAIM* is that the parents were all heterozygous for red eye color.
- You kept data showing both males and females with the trait because the unknown trait might be sex-linked. The data do not support a sex-linked trait but do support an autosomal trait; thus, you merge the data for males and females so you consider only the eye color in the cross. The *EVIDENCE* that supports your claim is the observed phenotypes and numbers seen in the chart. Both males and females show red and sepia eyes.

- From this evidence, you could write the following working hypothesis concerning the relationship between the dominant red eye color to the recessive sepia eye color: *If the parents are heterozygous for eye color, there will be a 3:1 ratio of red eyes to sepia eyes in the offspring.* Do your results support this hypothesis? Yes! So your *REASONING* could be a Punnett square that shows the offspring predicted from a cross of two heterozygotes.

CALCULATING CHI-SQUARE

The formula for Chi-square is

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

where:
o = observed number of individuals
e = expected number of individuals

- The actual results of an experiment are unlikely to match the expected results precisely. But how great a variance is significant? One way to decide is to use the Chi-square (χ^2) test. This analytical tool tests the validity of a **null hypothesis**, which states that there is no statistically significant difference between the observed results of your experiment and the expected results. When there is little difference between the observed results and the expected results, you obtain a very low Chi-square value; your hypothesis is supported.

Using the Chi-Square Critical Values Table

The Chi-square critical values table provides two values that you need to calculate Chi-square:

- **Degrees of freedom.** This number is one less than the total number of classes of offspring in a cross. In a monohybrid cross, such as our Case 1, there are two classes of offspring (red eyes and sepia eyes). Therefore, there is just one degree of freedom. In a heterozygous dihybrid cross, there are four possible classes of offspring, so there are three degrees of freedom.
- **Probability.** The probability value (p) is the probability that a deviation as great as or greater than each Chi-square value would occur simply by chance. Many biologists agree that deviations having a chance probability greater than 0.05 (5%) do not support the null hypothesis. Therefore, when you calculate Chi-square, you should consult the table for the p value in the 0.05 row.

Critical Values Table

	Degrees of Freedom (df)				
Probability (p)	**1**	**2**	**3**	**4**	**5**
0.05	3.84	5.99	7.82	9.49	11.1
0.01	6.64	9.21	11.3	13.2	15.1
0.001	10.8	13.8	16.3	18.5	20.5

Steps to Determining Chi-Square

1. **Set up a data chart as shown.** How do you figure out the expected phenotypes? Because your hypothesis predicted a 3:1 ratio in the offspring, you would expect 3/4 of the total offspring (44) to have red eyes = 33, and ¼ to have sepia eyes = 11.

Phenotypes	Observed (*o*)	Expected (*e*)	$(o - e)$	$(o - e)^2$	$\frac{(o - e)^2}{e}$
Red Eyes	31	33	2	4	4/33 = 0.12
Sepia Eyes	13	11	2	4	4/11 = 0.36
	44	44			Total = χ^2 = 0.48

2. **Determine the degrees of freedom.** This is the number of categories (red eyes or sepia eyes) minus one. For these data, the number of degrees of freedom is 1.
3. **Find the probability (*p*) value for 1 degree of freedom in the 0.05 row.** This is the **critical value**. For these data, the critical value = 3.84.
4. **Accept or fail to accept the null hypothesis.** The null hypothesis states that there is no statistically significant difference between the observed and expected data. Because the χ^2 value for this data is less than the critical value, you will accept the null hypothesis. This then supports your working hypothesis: *If the parents are heterozygous for eye color, there will be a 3:1 ratio of red eyes to sepia eyes in the offspring.*

Don't forget this little nugget: **If the Chi-square value is greater than the critical value, you fail to accept the null hypothesis** and consider reasons for this variation, such as errors in sample size or data collection.

> ***TIP FROM THE READERS***
> There was a Chi-square problem on the 2013 AP Biology Exam, and we found that a common error was that some students took the square root of the value they got for χ^2. Don't make this mistake! χ^2 is just the shorthand for the name of this mathematical technique: *Chi-square*.

Questions

1. You have a vial containing a red-eyed male with normal wings and a red-eyed female with normal wings. These are the F_1 generation. After two weeks, you collect the offspring from this pair and obtain the results shown in Figure 2. On the basis of the results shown in Figure 2, which statement is most likely true?

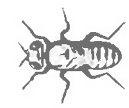
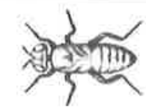
F$_2$ RESULTS	OBSERVED PHENOTYPE AND NUMBERS			
	Red eyes normal wings	Red eyes no wings	Sepia eyes normal wings	Sepia eyes no wings
♂ MALES	48 	13 	16 	4 
♀ FEMALES	50 	9 	10 	10 

Figure 2 Data table of *Drosophila* (2)

(A) The genes for red eyes and normal wings are linked.
(B) The gene for no wings is sex-linked.
(C) The F_1 mates were both homozygous for both eye color and wings.
(D) The gene for eye color is inherited independently from the gene for wings.

2. Based on the hypothesis that this is a dihybrid cross, with the two genes unlinked, calculate χ^2 using the data in the table of observed phenotypes.
(A) 6.043
(B) 7.815
(C) 4.977
(D) 24.038

3. Compare the Chi-square value obtained in question 2 with the Critical Values Table on page 355 for $p = 0.05$. Which of the following statements would be true?
(A) Because the calculated value for Chi-square is less than 7.82, the results support the hypothesis that the parents are heterozygous for two unlinked traits.
(B) Because the calculated value for Chi-square is less than 7.82, the results support the hypothesis that eye color and wings are linked.
(C) Because the calculated value for Chi-square is less than 7.82, the results are inconclusive. The experiment should be repeated.
(D) Because the Chi-square value is less than the critical value of 7.82, the null hypothesis is rejected for the hypothesis that the parents are heterozygous for two unlinked traits.

AP Biology Equations and Formulas

The following is the formula list that you will receive as part of your testing materials. *Source:* AP Biology—Course and Exam Description. © 2015. The College Board. www.collegeboard.org. Reproduced with permission.

Statistical Analysis and Probability

Standard Error

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

Mean

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

Standard Deviation

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

Chi-Square

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

Chi-Square Table

	Degrees of Freedom							
p	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.82	9.49	11.07	12.59	14.07	15.51
0.01	6.64	9.32	11.34	13.28	15.09	16.81	18.48	20.09

s = sample standard deviation (i.e., the sample based estimate of the standard deviation of the population)

$\bar{x}$ = mean

n = size of the sample

o = observed individuals with observed genotype

e = expected individuals with observed genotype

Degrees of freedom equals the number of distinct possible outcomes minus one.

Laws of Probability

If A and B are mutually exclusive, then P (A or B) = P(A) + P(B)

If A and B are independent, then P (A and B) = P(A) x P(B)

Hardy-Weinberg Equations

$p^2 + 2pq + q^2 = 1$ — p = frequency of the dominant allele in a population

$p + q = 1$ — q = frequency of the recessive allele in a population

Metric Prefixes

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Mode = value that occurs most frequently in a data set

Median = middle value that separates the greater and lesser halves of a data set

Mean = sum of all data points divided by number of data points

Range = value obtained by subtracting the smallest observation (sample minimum) from the greatest (sample maximum)

Rate and Growth

Rate
dY/dt

Population Growth
$dN/dt = B - D$

Exponential Growth
$$\frac{dN}{dt} = r_{max} N$$

Logistic Growth
$$\frac{dN}{dt} = r_{max} N \left(\frac{K - N}{K} \right)$$

dY= amount of change

t = time

B = birth rate

D = death rate

N = population size

K = carrying capacity

r_{max} = maximum per capita growth rate of population

Water Potential (Ψ)

$\Psi = \Psi p + \Psi s$

Ψp = pressure potential

Ψs = solute potential

The water potential will be equal to the solute potential of a solution in an open container, since the pressure potential of the solution in an open container is zero.

The Solute Potential of the Solution

$\Psi_S = -iCRT$

i = ionization constant (For sucrose this is 1.0 because sucrose does not ionize in water)

C = molar concentration

R = pressure constant (R = 0.0831 liter bars/mole K)

T = temperature in Kelvin (273 + °C)

Temperature Coefficient Q_{10}
$$Q_{10} = \left(\frac{k_2}{k_1} \right)^{\frac{10}{t_2 - t_1}}$$

Primary Productivity Calculation

mg O_2/L x 0.698 = mL O_2/L

mL O_2/L x 0.536 = mg carbon fixed/L

t_2 = higher temperature

t_1 = lower temperature

k_2 = metabolic rate at t_2

k_1 = metabolic rate at t_1

Q_{10} = the *factor* by which the reaction rate increases when the temperature is raised by ten degrees

Surface Area and Volume

Volume of Sphere
$V = 4/3 \pi r^3$

Volume of a cube (or square column)
V = l w h

Volume of a column
$V = \pi r^2 h$

Surface area of a sphere
$A = 4 \pi r^2$

Surface area of a cube
A = 6 a

Surface area of a rectangular solid
A = Σ (surface area of each side)

r = radius

l = length

h = height

w = width

A = surface area

V = volume

Σ = Sum of all

a = surface area of one side of the cube

Dilution - used to create a dilute solution from a concentrated stock solution

$C_i V_i = C_f V_f$

i = initial (starting) C = concentration of solute
f = final (desired) V = volume of solution

Gibbs Free Energy

$\Delta G = \Delta H - T\Delta S$

ΔG = change in Gibbs free energy

ΔS = change in entropy

ΔH = change in enthalpy

T = absolute temperature (in Kelvin)

pH = $-\log [H^+]$