Unit 7: Backyard Naturalist

Biology in a Box

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Unit 7: Backyard Naturalist
Materials List

- Set of 18 animal tracks cast in resin, labeled A-R
- Cloth bag
- Stopwatch
- Tape measure
- Rulers (6)
- Set of 8 animal scats (labeled A-H) in sealed plastic boxes
- Set of game cards with information on animals represented by the tracks & scats
- *The Animal Book*, a mini-field guide that provides identification sheets for the tracks and scats in this box, as well as information sheets on all the animals represented in these exercises (provided at the end of this book)
- Audio CD ("*Birdsongs & Things That Go Bump in the Night*")

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Introduction

As residents of Tennessee, we share the land with a wide variety of different plants and animals. Some animals are easy to find, because they live out in the open where we can see them. Many other animals, however, hide during the day and only come out at night. The tracks, poop (scat), and calls of these animals are evidence of their presence. Naturalists, or scientists who study the natural history (life cycles, diet, habitat, etc.) of organisms by observing them (or signs left by them) in their natural habitats, use tracks, scats, and other evidence to learn more about those organisms. In this unit, you will become naturalists yourselves, and learn a lot about some of our fellow animal residents of Tennessee, as other sorts of information that is useful to naturalists.

Exercise 1: Who Walked Here? focuses on animal tracks:

- **Exercise 1a: Matching Animal Tracks** presents students in grades K-1 with an opportunity to learn to recognize animal tracks by matching casts of animal tracks to identification sheets that show an animal's name, picture, and tracks.
- **Exercise 1b: Measure those Tracks** gives students a chance to record, organize, and analyze measurements of animal tracks. They will use their data to identify features that are shared by the feet of many different animal species, and search for biological explanations of the prevalence of these features.
- **Exercise 1c: Key those Tracks** presents students in higher grades with an introduction to taxonomic keys, and allows them to use a dichotomous key to identify tracks of the southeastern animals represented by the tracks in this trunk.
- **Exercise 1d: Bonus Game: Feel those Footprints** is an extension of the knowledge gained by students regarding the tracks that they have already learned.

In this fun exercise, students are challenged to use only the sense of touch to see if they can identify the tracks that they have learned, without relying on sight.

- **Exercise 1e: Fossil Footprints – How Fast Was that Dinosaur Moving?** introduces students to even more detailed information that can be learned about an animal through its tracks, with the help of a little math, as well as some data from real scientific research on animal biomechanics. Students will also empirically collect their own data to estimate speeds of dinosaurs based on their tracks.

Exercise 2: The Scoop on Poop focuses on animal scats:

- **Exercise 2a: Matching the Poop with the Pooper** presents young students (grades K-2) with an opportunity to learn the appearance of various animal scats by matching actual scat samples to pictures of scats, which are paired with images of the animals that left them.
- In **Exercise 2b: Using a Key to Identify Animal Scat** presents older students with a chance to further hone their proficiency in using taxonomic keys, through the use of another dichotomous key to identify various animal scat samples.
- **Exercise 2c: Grouping Animal Scats by Diet** is an exercise appropriate for all ages, allowing students to learn the similarities in appearance of scats left by animals of various diet types, a skill which is important in narrowing down the possible identities of unknown animal scats encountered in the field.

Exercise 3: Getting to know the Animals allows students to become even more well-versed naturalists, by learning the classes, orders, families, habitats, and diets of the animals represented by the tracks and scats in this box, through the use of a fun card-based memory game. This also reinforces some of their new naturalist knowledge, helping make mental connections among different types of signs left by animals.

Exercise 4: Bird Songs and Things that Go Bump in the Night focuses on auditory (sound) evidence of organisms:

- **Exercise 4a: How Many Different Birds Do You Hear?** provides younger students (grades K-2) with an opportunity to train their ears to pick out individual bird songs of different species in potentially noisy forest environments.
- **Exercise 4b: Identifying Individual Birds** helps older students (grades 3-12) learn and commit to memory the calls of 16 common southeastern bird species, and includes learning sessions, as well as practice quizzes.
- **Exercise 4c: Identifying Birds in Groups** allows older students to further hone their birding skills by training them to identify various bird species in the presence of other species' songs.
- **Exercise 4d: Sounds of the Night** is an exercise for all ages which allows students to learn to distinguish amongst the calls of nocturnal frogs, birds, and insects, as well as subgroups of each.
- **Exercise 4e: Visualizing Bird Songs** exposes students to introductory concepts of depicting sound visually. In this exercise, they are first given an opportunity to attempt to graphically represent various bird songs using their

own methods, before being introduced to actual graphical depictions of sound: spectrograms.

- **Exercise 4f: The Science of Sound** gives students further information on acoustics, including the concept of pressure waves, how spectrograms are actually constructed, and creative applications of the mathematics of sound.

Exercise 1: Who Walked Here?

One of the best ways to tell which animals are in your backyard is to look for their tracks. Every species of animal has unique feet, and when they travel over soft ground, they leave unique footprints behind. In this exercise, you will play the role of detectives trying to identify animals by their tracks. As you complete the animal track identification exercises, we want you to consider the following "Super Solver" question: What additional information can we learn about an animal by examining its tracks? Check your answer to this question under the answers for **Exercise 1** at the end of this book.

Exercise 1a: Matching Animal Tracks (*Grades K-1*)

Materials:

- Set of animal tracks cast in resin
- Track identification sheets which display an animal's name, picture and tracks (found on pages 52-55 of this book)

Instructions:

- Choose one of the identification sheets.
- Find the animal track that matches the track in the box.
- Look at the picture of the animal that made the track.
- Read the name of the animal whose picture and track.
- Repeat these steps for all of the animal sheets available.

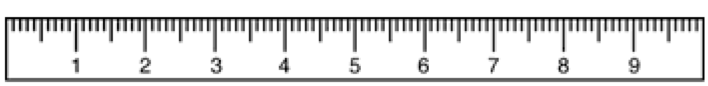
Exercise 1b: Measure Those Tracks (*Grades 3-12*)

Materials: Set of animal tracks cast in resin
Small ruler
Scientific calculator

In this exercise, you will collect, organize, and analyze animal track measurements.

- Find the set of animal tracks cast in resin.
- Select an animal track to identify.
- Note the letter on the track's label.
- Use the ruler to measure the tracks, and record your measurements in the table on page 9. You should measure the length of the front foot, the length of the back foot, the width of the front foot, and the width of the back foot in centimeters. (Note that some of the tracks only show one foot, so you will not be able to complete every measurement for every species. In this case, you should consider the foot to be a back foot, and complete as much of the table as possible.)
- Use your centimeter ruler to measure the tracks, and record your measurements in the table on page 9.
- You should measure the length of the front foot, the length of the back foot, the width of the front foot, and the width of the back foot in centimeters.

Your centimeter ruler will look something like the picture below with each numbered section divided equally into ten smaller sections. (If your ruler also has inches on one side, be sure to only use the centimeter side of the ruler for this exercise!) The numbers represent centimeters, while the smaller sections represent millimeters. Each centimeter is divided into 10 equal sections, so each millimeter is 1/10 of a centimeter. If you measure a length that is 2 small sections past the number 3, then you have two centimeters + 2 millimeters, which is written 3.2, meaning 3 and two-tenths centimeters.



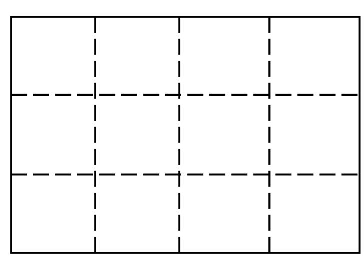
- Use your measurements and a calculator to perform the necessary calculations and complete the table.
- For calculating the area of a particular footprint, you could simply use the formula for the area of a rectangle (Area = length × width). However, if you wish to obtain more accurate estimates of area, you could decide on which

of the following geometric shapes below most closely describes a particular track, and use the corresponding formula for the area of that shape:

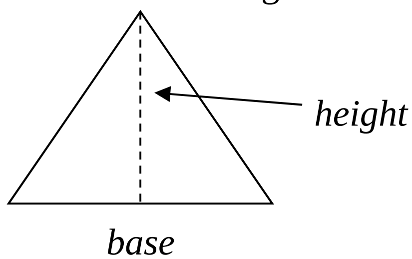
Area is the measure of the space inside a region. You can also say area is a *measure of covering* because it measures how much space would need to be covered to completely fill in the figure. For example, the area of a rectangle is the space within, or inside, the edges of the rectangle. How area is measured depends on the shape of the figure. Rectangles, triangles, circles, ellipses, and trapezoids all have different **formulas,** or methods, for finding area.

Rectangles: Look the rectangle below. This rectangle is 4 units across (length) and 3 units down (width). Both the length and width of the rectangle have been divided into those units with dashed lines to show you the amount of covering it takes to completely cover the space inside the rectangle. Count the number of individual squares made by the dashed lines inside the rectangle. How many do you find? Look closely at the length and width of the rectangle. The length of the rectangle is 4 units, and the width of the rectangle is 3 units. What is 4 × 3? Is the answer to 4 × 3 the same number you got when you counted the squares inside the rectangle? (It should be!) The formula for finding the area of a rectangle is below, with with *l* being the length and *w* being the width.

$$\boldsymbol{A = l \times w}$$



Triangles: If your shape is a triangle, there is a unique way of finding its area, also. Look at the triangle below. The dashed line indicates the height of the triangle, which is the distance from the base, or bottom, of the triangle, to the opposite vertex, which is the 'corner' of the triangle directly across from the base of the triangle.



To find the area of the triangle, *multiply the base times the height and divide by 2*. Or, to say the formula another way, the formula for finding the area (A) of a triangle is

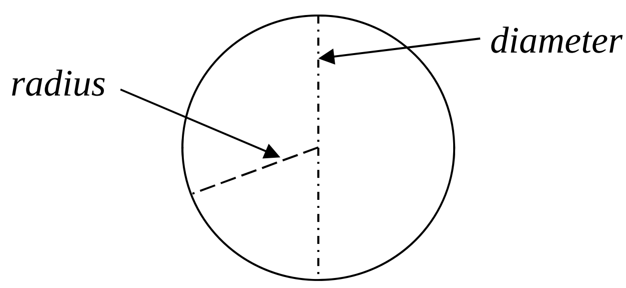
$$A = \frac{1}{2} b \times h$$

Circles: The formula for finding the area of circles is

$$A = \pi r^2$$

The symbol π (called **pi**, which is pronounced *pie*, like the ones you eat!) is the relationship between the circumference of the circle and the diameter of the circle. If you divide the circumference of a circle by its diameter, you find that your quotient will always be approximately 3.14. If you are finding the area of a circle, use 3.14 as the number that represents π in the formula. The **circumference** of a circle is the distance around the circle.

To complete finding the area of a circle, you must also know the **radius** of the circle, which is represented by r in the formula. The radius of a circle is one half the **diameter**. If you draw a line from a point on the circle and across to the other side so that it passes through the center of the circle, your line represents the *diameter* of the circle. The *radius* of the circle is half the length of the diameter and is shown by a line from the center of the circle to a point on the circle. Look at the diagram of the circle shown below and notice the line that goes all the way across the circle is the *diameter*, and the line that goes only halfway across the circle is the *radius*.

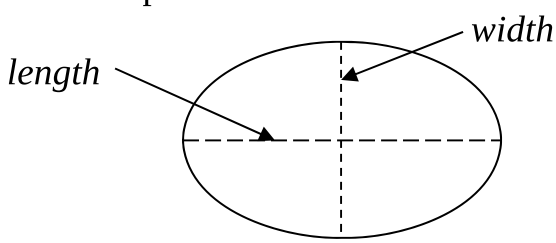


In the formula for area of a circle, you also will notice a small "**2**" just above the "**r**." We call the expression r^2 a **power**. The small 2 is an **exponent**, and the **r** is called the **base**. The exponent tells you how many times the base number (in this case, **r**) will be a factor. Whatever you measure your radius (**r**) to be, you will multiply that number by itself. For example, if the radius of a circle is 5 cm, then to

find 5^2, you will have 5 (5 is the base number) as a factor 2 times (2 is the exponent) so you would multiply 5 × 5 to get 25cm. If the radius of a circle is 3 cm, then to find 3^2, you would multiply 3 × 3 to get 9cm (3 is a factor two times).
Ellipses: An ellipse is an oval-shaped curved figure. If you need to find the area of an ellipse, you will use the formula

$$A = \pi \times width \times length$$

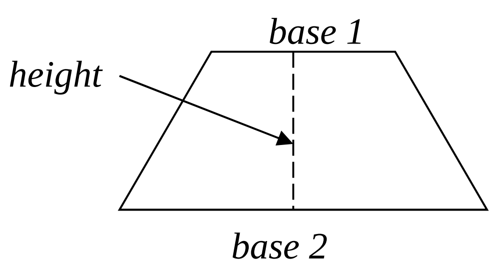
You will use 3.14 for π just as you do for circles. The width of the ellipse should be measured at its widest point, and the length of the ellipse should be measured at longest point. Look at the ellipse shown below.



Trapezoids: The formula for finding the area of a trapezoid is

$$A = height \times \tfrac{1}{2} \times (base\ 1 + base\ 2)$$

Look at the trapezoid below with the height and both bases labeled. The bases are the two sides that are *parallel* to each other. You will need to measure the length of both bases and find the sum of those lengths (add the bases together). You will also measure the height of the trapezoid. Using the formula, you will multiply the height by ½, which is the same as dividing by 2. Multiply that number by the sum of the bases to find the total area of the trapezoid. For example, let's say base 1 measures 5 cm, base 2 measures 7 cm, and the height measures 6 cm. Find the sum of the bases: 5 + 7 = 12. Multiply the height 6 by ½ (divide by 2): 6 × ½ = 3. Multiply 3 (half the height) by the sum of the bases (12). This gives us 3 × 12 = 36. Thus, the area of the trapezoid is 36 square centimeters (36 cm^2).



track label	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
length (front foot)																		
length (back foot)																		
width (front foot)																		
width (back foot)																		
area (front foot)																		
area (back foot)																		
(back foot length)/ (front foot length)																		
(back foot width)/ (front foot width)																		
(back foot area)/ (front foot area)																		

Note that the final three rows of the table contain ratios, that is, numbers that represent the division of one number by another. Recall that if the ratio of two numbers is bigger than one, then the first number (the dividend) is bigger than the second number (the divisor). If the ratio of two numbers is smaller than one, then the second number is bigger than the first number.

Use the final three rows of your table to answer the following questions.

Q1. In general, how does the length of an animal's back foot compare to the length of its front foot? Is one foot usually longer, or are they about the same length? Explain how the data in your table support your answer.

Q2. In general, how does the width of an animal's back foot usually compare to the width of its front foot? Is one foot longer usually wider, or are they about the same width? Explain how the data in your table support your answer.

Q3. In general, how does the area of an animal's back foot usually compare to the area of its front foot? Does one foot usually have a larger area, or are they about the same size? Explain how the data in your table support your answer.

Q4. Can you think of some biological reasons for the trends in foot length ratios, foot width ratios, and foot area ratios that you observed? Think about how animals use their feet, and how the functions of back feet may differ from those of front feet. You might start by thinking about your own back feet (feet) and front feet (hands).

Q5. Can you think of any biological reasons why the trends you observed in foot length ratios might differ from those you observed in foot width ratios? Hint: In what direction do most animals move?

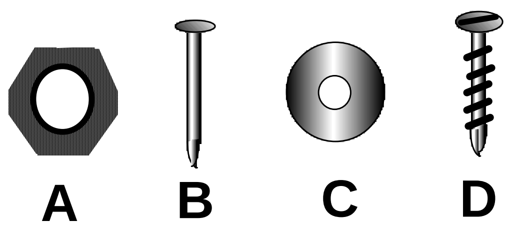
Exercise 1c: Key Those Tracks (*Grades 3-12*)

Materials: Set of animal tracks cast in resin
Completed data table from **Exercise 1b.**

Using a Key

A key is a guide that helps you to identify what something is. It is a series of descriptive pairs, or **couplets**. From each descriptive couplet, beginning with the first, you should select the description which best fits the object that you are trying to identify. Once you select the description that best fits your object, you will either be instructed to move to another descriptive couplet, or be told the object's name. Because you are always choosing the best option from a *pair* of descriptions, this key is called a **dichotomous (two choice) key**.

Below is an example of a dichotomous key designed to distinguish between items A-D below.



Key:

1a. Object has a hole in the center....................................go to couplet 3
1b. Object does not have a hole in the center...................go to couplet 2

2a. Object has a groove in the top ....It is a Screw
2b. Object does not have a groove in the top...........................It is a Nail

3a. Object is hexagonal ....It is a Nut
3b Object is circular ....…It is a Washer

Example: We will show you how to use this key to identify object A.

- Start at the first couplet (1a & 1b) and read both of the options. Since item A has a hole in it, we choose description 1a, which tells us to go to couplet 3.
- Read both options for couplet 3. Since item A is hexagonal, we choose description 3a, which tells us that the item is a nut.

- Now use the key to identify objects B-D.

Once you feel comfortable using a dichotomous key, you can use this skill to identify the animals that made the tracks in the box.

- Find the set of animal tracks cast in resin.
- Select an animal track to identify.
- Note the letter on the track's label.
- Use the dichotomous key on pages 13-14 to find the name of the animal that made the track. You will need to use the data that you collected in the previous exercise to navigate the key.
- Use the answer sheet for **Exercise 1b** to check your answer.
- Repeat these steps until you have identified all of the tracks.

The Backyard Naturalist Key to Animal Tracks

Directions: Begin at the first descriptive couplet. Read both of the descriptions, and select the one that best describes the track that you are observing. Follow the directions that go with the description that you have chosen. Continue until you identify the track.

Below are some features of tracks with which you should be familiar.

1a. Track triangular/fork-shaped, with three forward-pointing toes, & one backward-pointing toe.Go to 2
1b. Tracks not as above.. Go to 3

2a. Track shows distinct webbing between toes .... Go to 4
2b. Track does not display webbing .... Go to 5

3a. Tracks heart-shaped, showing only two toes per foot...White-tailed deer
3b. Tracks not as above...Go to 6

4a. Track nearly as wide as it is long .... Canada Goose
4b. Track clearly longer than wide .... Mallard Duck

5a. Track less than 6 cm long.. American Crow
5b. Track greater than 6 cm long .... Great Blue Heron

6a. Claws not visible on track(s).. Go to 7
6b. Claws clearly visible in at least the front or hind track..Go to 8

7a. Track mostly round, with a clear foot pad and four similarly-sized toe pads................ Mountain Lion
7b. Tracks more elongated, with variable toes, or toes difficult to see.. Go to 9

8a. Track appears scaly ....Common Snapping Turtle
8b. Track does not appear scaly...Go to 10

9a. Elongated toes of differing sizes visible; track may display webbing..................................... Bullfrog
9b. Toes difficult to see in track, may appear obscured from prints of thick fur............ Eastern Cottontail

10a. Track shows only four toes on both front and hind feet ....Red Fox
10b. Track shows more than four toes on either (or both) front/hind foot ....Go to 11

11a. Track shows five toes on both feet...Go to 12
11b. Track shows four toes on front foot, and five toes on hind foot...Go to 13

12a. Foreprint may only show 4 toes (5th toe is much smaller), hind track may appear webbed... Muskrat
12b. Tracks not as above...Go to 14

13a. Hind print greater than 5 cm (50 mm) long ....Eastern Grey Squirrel
13b. Hind print less than 5 cm (50 mm) long ....Eastern Chipmunk

14a. Hind track nearly as wide as long; tracks may appear webbed.. River Otter
14b. Hind tracks clearly longer than wide, no webbing present...Go to 15

15a. Claws clearly visible on foreprints, less so (or not present) on hindprints ....Striped Skunk
15b. Claws clearly visible on both foreprints and hindprints ....Go to 16

16a. Foreprint 30-40 mm wide..Mink
16b. Foreprint greater than 40 mm wide..Go to 17

17a. Hindprint with "thumb" toe angled greatly away from other toes........................... Virginia Opossum
17b. Hindprint not as above ....Raccoon

NOTE: The key above will work only for the tracks presented in this box. If you want to identify other animal tracks you might find in your area, check out the "*Suggested Reading*" and "*Links*" sections of this book for other track identification resources!

Exercise 1d: Bonus Game: Feel Those Footprints! (*Grades K-12*)

Imagine that you are out camping in the woods one night when you hear an animal walk by your tent. Your fire has already burned out, and your flashlight batteries are dead. Can you identify the animal by feeling its tracks? Have your teacher or a friend put a track inside the cloth bag while your back is turned. Reach in and see if you can identify the track by feel alone. Then take the track out and see if you were right!

Exercise 1e: Fossil Footprints: How fast was that dinosaur moving? (*Gr. 7-12*)

In this exercise, you will learn how to estimate the speed at which an animal was traveling by measuring the stride length of its tracks. This technique can help us learn about extinct organisms that we cannot study directly, such as large mammals that once roamed North America and other continents, and even dinosaurs. You can use this same method with any set of recent tracks you come across in the mud, sand, or snow, and should do so as an extension of the formal exercise you complete here.

To complete this exercise, you will need to understand metric measurement. You will be measuring lengths, so you will be measuring using **meters** as your base unit. In order to accurately measure in the metric system, it is important for you to know how the system works.

The metric system is based on multiples of ten. If you look at your metric ruler or meter stick, you will see the very smallest units marked on the edge of the ruler. Those very small units are millimeters. The prefix **milli-** tells you that each of those small sections represents 1/1000 of a meter (0.001), meaning there are 1000 millimeters in a meter.

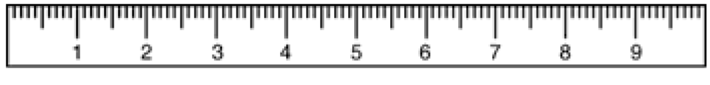
Ten of those very small sections (millimeters) represents one centimeter. The prefix **centi-** tells you that length represents 1/100 (0.01) of a meter, which means there are 100 centimeters in a meter. If there are ten millimeters in every centimeter, and you have a length of 100 centimeters, you then have one meter. Below are some relationships between various units of length in the metric system.

10 mm = 1cm

100 cm = 1m

1000 mm = 1m

- Look at the metric ruler below.



The smallest spaces marked on the ruler represent millimeters, and the numbers you see on the ruler represent centimeters. If you count the number of those very small spaces between the numbers, you will see there are ten spaces, or millimeters, in each centimeter. (Be sure and count the spaces, not just the lines drawn between the spaces.) If you are measuring a length in centimeters and you find the length to be 4 small spaces after the number 5 on the ruler, then you have 5 whole centimeters and 4/10 of another (or 4 millimeters). This is written 5.4cm (read *five and four tenths centimeters*). Always use decimal numbers when using the metric system and always label your lengths with the appropriate units.

You will be finding lengths in this exercise that call for you to measure in meters. Since there are 100 centimeters in one meter, you will need to know how to write your measurements to indicate meters. If you measure a length to be 2 whole meters with an additional 9 centimeters, that means your length is 2.09 meters (2 whole meters plus 9/100 of another meter since one centimeter is equal to 1/100 of a meter). If you measure a length of 5 whole meters and 24 additional centimeters, your length will be written 5.24 (5 whole meters plus 24/100 of another meter). Let's say you measure a length of 4 meters plus 18 centimeters plus 3 millimeters. Since you know that there are 10 millimeters in every centimeter, multiply 18 x 10 to get 180, which tells you there are 180 millimeters in 18 centimeters. Add the three additional millimeters to 180 for a sum of 183 millimeters. You know that one millimeter is 1/1000 of a meter, so that means 183 millimeters is 183/1000 of a meter, or 0.183. Your length will be 4.183 (4 whole meters, and 183 thousandths of another meter).

Before beginning this exercise, you need to know something about data analysis, as well as about a few physical principles associated with the field of **biomechanics**, which is the science of movement of a living body.

Methods of Data Analysis:

You are probably already familiar with **univariate** data, in which you measure one variable or parameter, such as the height of individuals in your class (the, suffix *uni*- means "one"). In this exercise, you will be asked to analyze a set of **bivariate data**, involving two variables (the prefix *bi*- means "two"), such as body weight and height.

Q1. If you measure and record each student's height, weight, and age in your class, will you have created a set of bivariate data? Why or why not? What are the variables in this data set?

- Look at Figures 1 & 2 on page 18.

Figures 1 & 2 represent the measurements made on foot length and leg length for three animals. These measurements are referred to as **data**, and each measurement is a datum or represents a data point. Collectively, data form a **data set**. Thus, Table 1 is a set of bivariate data, with the vertical columns representing the variables measured, and the rows representing the values of the respective variables for the individuals measured.

Graphs such as the ones in these figures give us a picture of how one variable changes as another variable changes. How does your height compare to your age as you get older? How does your weight compare to your height as you get older? In both of those comparisons, as one variable changes, the other variable also changes. When a set of data is bivariate, we can visualize the data by creating a **scatter plot**, in which the value of one of the variables is plotted along the horizontal plane or x-axis and the value of the second variable is plotted along the vertical plane or y-axis, as shown in the following figures. The graphs you will be working with in this exercise are called **scatter plots**, because the plots show points in a way that sometimes looks as if they have been *scattered* about the graph.

If you can draw a line through your plot that projects through the middle of the set of points and as close to the 'center' of the set of points as possible, then you can say the graph indicates a **linear relationship**. The root word of *linear* is *line,* so that means the points on the graph show a definite trend on or near a line we could draw on the graph to show a trend either upward or downward as we move from left to right on the graph. The line is called the **best fit line**, because it fits as closely as possible to the complete data set even though it cannot project through each individual point.

- Look at the data points in Figure 1 on page 18.
- Now observe the *best fit line* added to those same data points in Figure 2.

Even though the line does not project through all the points, it does show the trend represented by the data points. The line is very close to all the points. The best fit line allows you to detect the trend in your data and to predict what additional data might show if you were to collect more data for the same exercise. The closer the points on the plot are to each other, the more likely it will be to predict trends in the data. The further apart your points are on your plot, or if they are scattered about the plot with no obvious trend, the likelihood of being able to use the data to make any kind of predictions is extremely limited.

Q2. Does it look like there is a linear relationship between foot length and leg length? Why do you think this is the case?

Table 1: Foot length and leg length in centimeters (cm)

	Foot length (cm)	Leg length (cm)
1	17.8	83.6
2	25.4	101.6
3	22.9	89.7

Figure 1. Leg length plotted against foot length

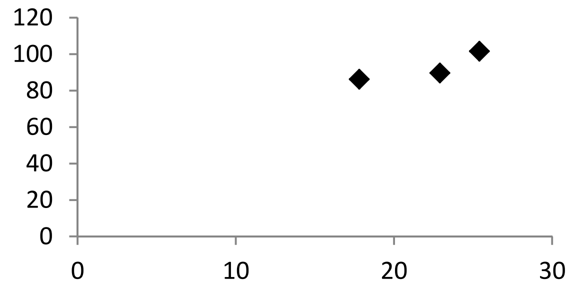
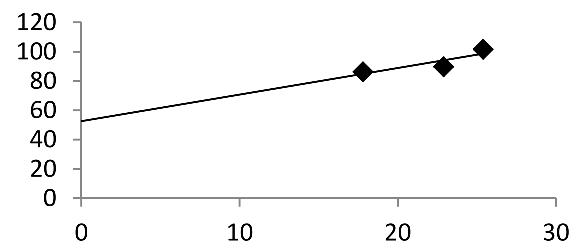
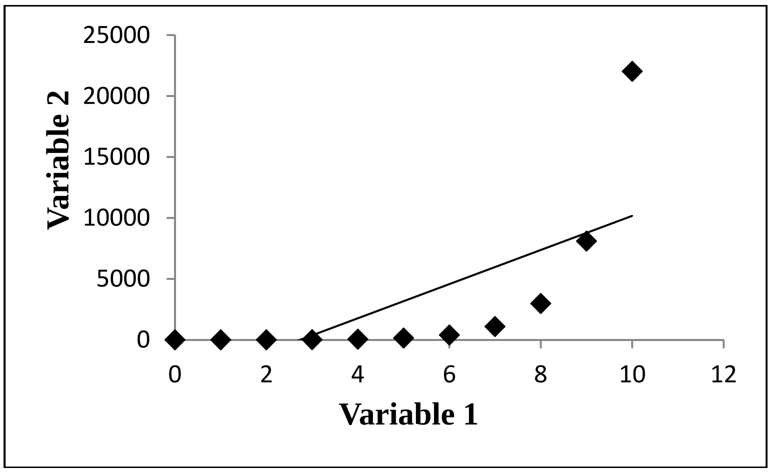


Figure 2. Leg length plotted against foot length, with best fit line added



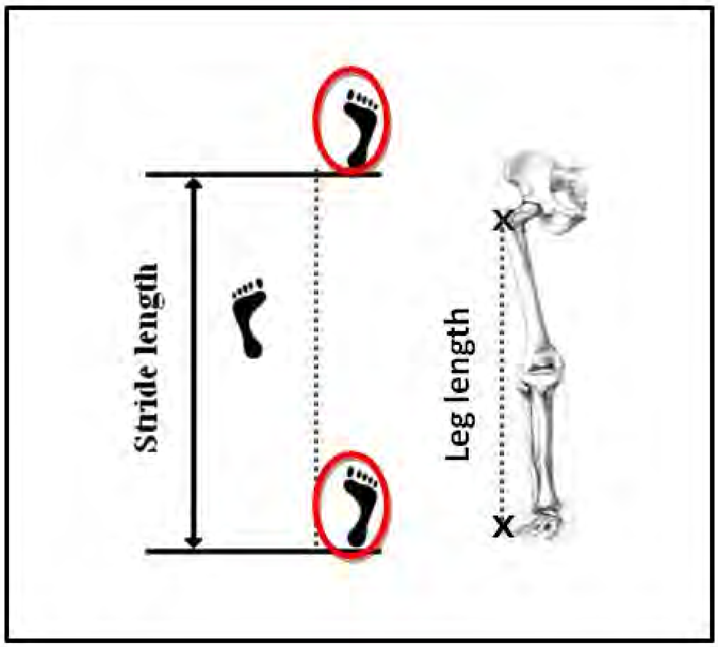
Q3. Does it look like there is a linear relationship between the variables shown in Figure 3 below?



Biomechanics:

In order to complete this exercise, you will need to make several physical measurements and compute new parameters from them. Figure 4 shows two of the parameters that interact in determining the speed at which an animal is traveling, stride length and leg length.

Figure 4. Illustration of stride length and leg length.



The **stride length** is the distance between two consecutive prints made by the same foot (circled in Figure 4).

The **leg length** is the distance from the hip joint to the base of the foot (represented by the dashed line between the X's in Figure 4).

The **speed** is the distance traveled divided by the time it took to travel that distance, or expressed mathematically, $\boldsymbol{speed = \frac{distance}{time}}$.

Scientists measure all of these quantities using standard units. For each of these measures, length and distance are measured in meters, and time is measured in seconds. You should use these same units when completing this exercise.

In completing this exercise, a quantity known as the **dimensionless speed** is of interest to us. Dimensionless speed is calculated as the speed divided by the square root of the product of leg length and the gravitational constant, which is equal to 9.81 meters per second squared.

$$dimensionless\ speed = \frac{speed\ m/s}{\sqrt{(leg\ length \times 9.81\ m/s^2)}}$$

In the previous formula, speed is measured in meters per second, and leg length is measured in meters.

- Examine the equation for dimensionless speed and answer question 4.

Q4. What does it mean for a number to be dimensionless? Explain why the dimensionless speed is indeed dimensionless.

Relating relative stride length and dimensionless speed:

Stride length and speed are directly related, with longer stride lengths typically leading to faster travel. Given enough measurements (data points), we can find an equation that relates animal stride length to speed. This equation, however, is not the same for all animals, and tends to vary with an animal's size.

Exercise 1e.1: Repeating Alexander's Experiment.

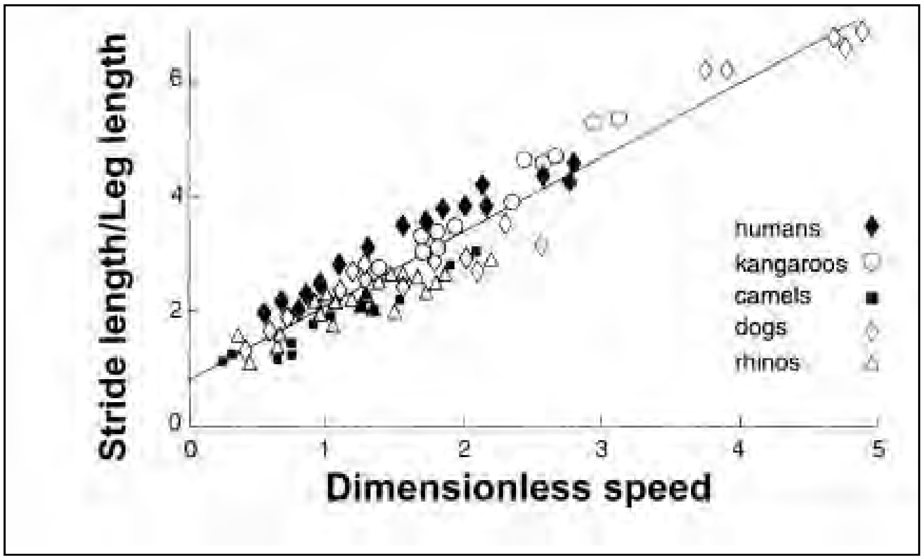
R. McNeill Alexander, a scientist from the University of Leeds in England , discovered that while the relationship between stride length and speed is influenced by an animal's size, the relationship between **relative stride length** and **dimensionless speed** *can* be described by an equation that holds for animals of all sizes. We know how to compute dimensionless speed from the equation presented above. How do we obtain a value for relative stride length?

The **relative stride length** is the stride length divided by the leg length.

$$relative\ stride\ length = \frac{stride\ length}{leg\ length}$$

Alexander measured the relative stride length of many different animals while they were traveling at many different speeds. After plotting these data, he observed that the relationship between relative stride length and dimensionless speed was approximately linear. Figure 5 below is a scatter plot of Alexander's data. The best fit line for the data (with an approximate equation of $\boldsymbol{y = 1.1x + 1}$) is also shown.

Figure 5: Alexander's plot of relative stride length vs. dimensionless speed



In this exercise, your class will perform an experiment much like Alexander's to determine how relative stride length and dimensionless speed relate to one another. First, you will collect data on the relative stride length of several students traveling at both walking and running speeds. Then you will plot these data on a scatter plot in order to find a linear equation that fits these data. You will then use your equation to estimate the speed at which two dinosaurs traveled, and compare your results to Alexander's.

The experiment:

NOTE: During each of the following trials, it is very important that the timer starts the stopwatch as soon as he or she says "go," and stops the time as soon as the traveler's foot hits the ground for the sixth time. It is also very important that the traveler strives to maintain a constant speed, and that after completing the sixth step, the traveler does not move until the distance traveled has been recorded.

1. Divide the class into teams of 3-4 students each.
2. Measure the length of each student's leg, from the hip joint to the base of the shoe. (To find your hip joint, press your hand against the side of your pelvis and swing your leg back and forth. As you swing your leg, you should be able to feel your hip joint moving.)
3. Record each student's leg length in a data table that has leg length as a column, and the name of each individual as each row.
4. For each trial, one student on a team will be the timer, a second student will be the traveler, and the third or fourth student will mark the ending point of the distance traveled.
5. Place a piece of tape at one end of the hallway, track, or open space in the classroom.
6. At the beginning of the trial, the traveler stands in a ready position, with his or her front heel* just touching the starting tape. **(* Note that we are measuring strides from heel to heel here, corresponding to Figure 4. One could just as easily and accurately calculate stride length using a toe-to-toe measurement as shown in Figure 6).**
7. When the timer says "go," the traveler should take six walking steps and stop, holding his or her position. Simultaneously, the timer should stop the stopwatch just as the traveler's foot hits the ground on his/her sixth step.
8. The marker places a piece of tape at the back of the heel of the traveler's front foot.
9. Next, measure the distance from the starting tape to the finish tape in meters. Be sure that you are consistent in your measurements and starting positions, so that your measurements always reflect the distance from the back of the traveler's front heel at the start to the back of the traveler's front heel at the finish.
10. Record this distance in a second column labeled '*Distance Traveled*', which you have added to your data table. Make sure that the distance a traveler moves corresponds to that traveler's leg length in the table (their leg length and distance traveled should be in the same row, under the proper column headings).
11. Also record the time it took the traveler to complete their six steps in a third column labeled "*Walk Time*" (again, this should be in the same row as the other measurements collected for that traveler).
12. Repeat steps 7-11 with running steps in place of walking steps, placing the "*Run*" data in a separate table from the "*Walk*" data.
13. Repeat steps 7-12 two more times until every student in the group has been the traveler.

14. Add columns labeled "*Stride Length*", "*Relative Stride Length*", "*Speed*", and "*Dimensionless Speed*" to your tables. Example tables, including how to calculate values for each of these columns, are provided below.

Data tables for empirically estimating a linear relationship between dimensionless speed and relative stride length.

2a. Walk

Name	**Leg Length (m)**	**Total Walk Distance (m)**	**Walk Time (s)**	**Stride Length (m)** $= \frac{walk\ dist.}{3}$	**Relative Stride Length** $= \frac{stride\ length}{leg\ length}$	**Speed (m/s)** $= \frac{walk\ dist.}{walk\ time}$	**Dimensionless Speed** $= \frac{speed\ m/s}{\sqrt{(leg\ length \times 9.81\ m/s^2)}}$

2b. Run

Name	**Leg Length (m)**	**Total Run Distance (m)**	**Run Time (s)**	**Stride Length (m)** $= \frac{run\ dist.}{3}$	**Relative Stride Length** $= \frac{stride\ length}{leg\ length}$	**Speed (m/s)** $= \frac{run\ dist.}{run\ time}$	**Dimensionless Speed** $= \frac{speed\ m/s}{\sqrt{(leg\ length \times 9.81\ m/s^2)}}$

NOTE FOR TEACHERS: Since only one tape measure and stopwatch are provided in this unit, only one group at a time will be collecting data for this exercise. During this time, you may wish to have other groups work on the exercise to estimate dinosaur speeds, or to do some internet research to find images of animal tracks and/or data on leg lengths of animals for which they may find track images, or whose tracks they might encounter in the field.

Data Analysis:

Rate is way of expressing how something is changing. For example, the speed a car travels is indicated by miles per hour, the gas mileage of a car is indicated by miles per gallon, and a worker's hourly pay is indicated by dollars per hour. You will also notice that in each of those examples, all the rates include two different units: *miles* per *hour*, *miles* per *gallon*, and *dollars* per *hour*. The two different units tell how one unit, or variable, changes as the other variable changes. The longer the distance you drive in a shorter time, the more progress you make in getting to your destination. The more miles you drive, the more gas you car uses. You are paid more if you work more hours.

When we graph a comparison of variables (dollars per hour, for example), we often want to see how one variable is changing as the other variable changes. This rate of change is also called the **slope** because, when the data are graphed, we look to see the trend of the points on the graph. Is there an upward or downward trend in the location of the points as you look from left to right on the graph? Think of the word *slope* and how you use it. A hill slopes upward or downward, and that is what slope describes in graphs. The slope can be very steep, it can be very subtle, or there may not be an upward or downward slope at all. It all depends on how the variables relate to each other.

The steepness of the line on your graph can be measured and given a specific value. Since you are using a coordinate grid to plot your points, you use the x- and y-axis to help you find the slope. Think of slope as comparing the *rise* of the line to the *run* of the line between two specific points on the line, with the rise being how many units the line moves up or down the y-axis compared to how many units the line runs horizontally to the left or right along the x-axis. You are going to compare the number of units of rise or fall are between the two points relative to the y-axis, as well as how many units to the left or right are between the points relative to the x-axis.

- For all students in the class, plot each student's relative stride length versus the dimensionless speed when both walking and running on the same graph.
- Draw a line through your data points so that as many points are as close to your line as possible. (There is a statistical procedure to find the actual 'best fit' line for your data, but for our purposes, your best guess will suffice.) The line you have drawn is described by a linear equation of the form

$$y = mx + b$$

The slope of the line is m, and the y-intercept (the point where the line crosses the y-axis) of the line is b. This form of the equation for a line is known as the **slope-intercept equation** of a line.

- Estimate the value of two points on your line, $(\boldsymbol{x_1}, \boldsymbol{y_1})$ and $(\boldsymbol{x_2}, \boldsymbol{y_2})$. These points need not be data points. They just need to fall *on your line*.

- Calculate the slope, m, of your line using the **point-slope formula**

$$m = \frac{\boldsymbol{y_2} - \boldsymbol{y_1}}{\boldsymbol{x_2} - \boldsymbol{x_1}},$$

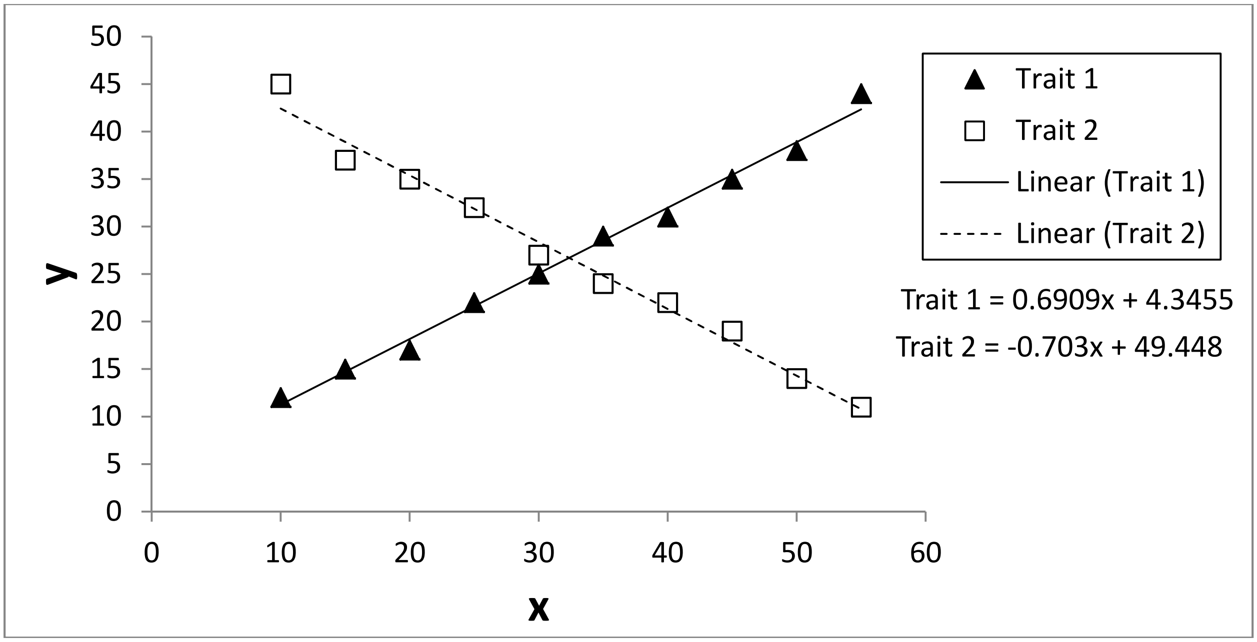
See below for an example of calculating the slope of a line.

> **Example calculation of the slope of a line:** If the points (2,4) and (4,9) both fall on the line, then the slope of the line is equal to

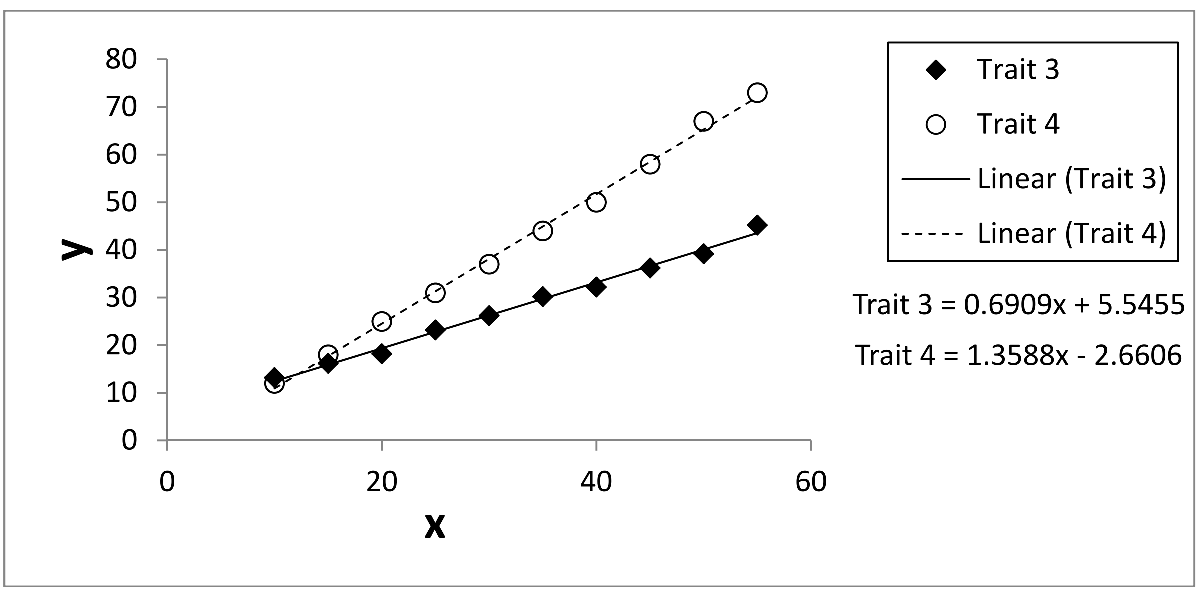
$$m = \frac{9 - 4}{4 - 2} = \frac{5}{2} = 2.5$$

Why are scientists interested in slopes of lines? What can slopes tell us? For one thing, the slope of a line tells us if one variable increases or decreases as the other variable increases.

- Examine the data presented in the figure on the following page. Note that the value of trait 1 increases with increasing value of $\boldsymbol{x}$. Notice also that the slope is positive in the equation of the best fit line for Trait 1. Another way of saying this is that x and Trait 1 are **positively correlated**.
- On the other hand, note that the opposite is true for trait 2. Here, as the value of x increases, the value of Trait 2 decreases, Further, the best fit line for Trait 2 has a negative slope: x and Trait 2 are **negatively correlated**.



The slope of a line can also tell us how *quickly* one variable changes relative to changes in the other variable. For example, in the figure on the below, you can see that as the value of x increases, the values of both Traits 3 and 4 also increase. Thus, the slopes of the best fit lines for each of those traits are positive (both traits are positively correlated with ***x***). However, the slope of the best fit line for Trait 4 has a larger value. This means that as x increases, the value of Trait 4 increases at a faster rate than the value of Trait 3, and the best fit line for Trait 4 has a steeper slope.



- Use your calculated slope ($\boldsymbol{m}$) for the relationship between relative stride and dimensionless speed and a point on your line, designated here as $(\boldsymbol{x_1}, \boldsymbol{y_1})$, to rearrange the point-slope formula below to obtain the general slope-intercept equation of your best fit line.

$$\boldsymbol{m} = \frac{\boldsymbol{y} - \boldsymbol{y_1}}{\boldsymbol{x} - \boldsymbol{x_1}}$$

Example: If (2,4) is a point on the line and $m = 2.5$, then the point slope formula becomes

$$2.5 = \frac{y - 4}{x - 2}$$

By solving for y, as outlined below, we can easily rearrange this into the slope-intercept format for the equation of a line.

$$2.5 = \frac{y - 4}{x - 2} \rightarrow$$

$$2.5(x - 2) = y - 4 \rightarrow$$

$$2.5x - 5 = y - 4 \rightarrow$$

$$y = 2.5x - 1$$

Comparing this with the general slope intercept form of the linear equation ($y = mx + b$), we see that $b = -1$. This means that the graph of the line crosses the y-axis at a value of -1, or at the point with the coordinates (0,-1). **Note: When a line crosses the y-axis at the y-intercept, the x-coordinate is always equal to 0. If you know the equation of a line, you can calculate the y-intercept by substituting 0 for *x* and solving for *y* in the slope-intercept formula.**

- Record the equation of your best fit line.

Q5. Based on the slope of your line, do relative stride length and dimensionless speed appear to be positively or negatively correlated? Is this similar to the pattern noted by Alexander?

Q6. How well does your best fit line appear to fit the data? Are the points clustered close to the line?

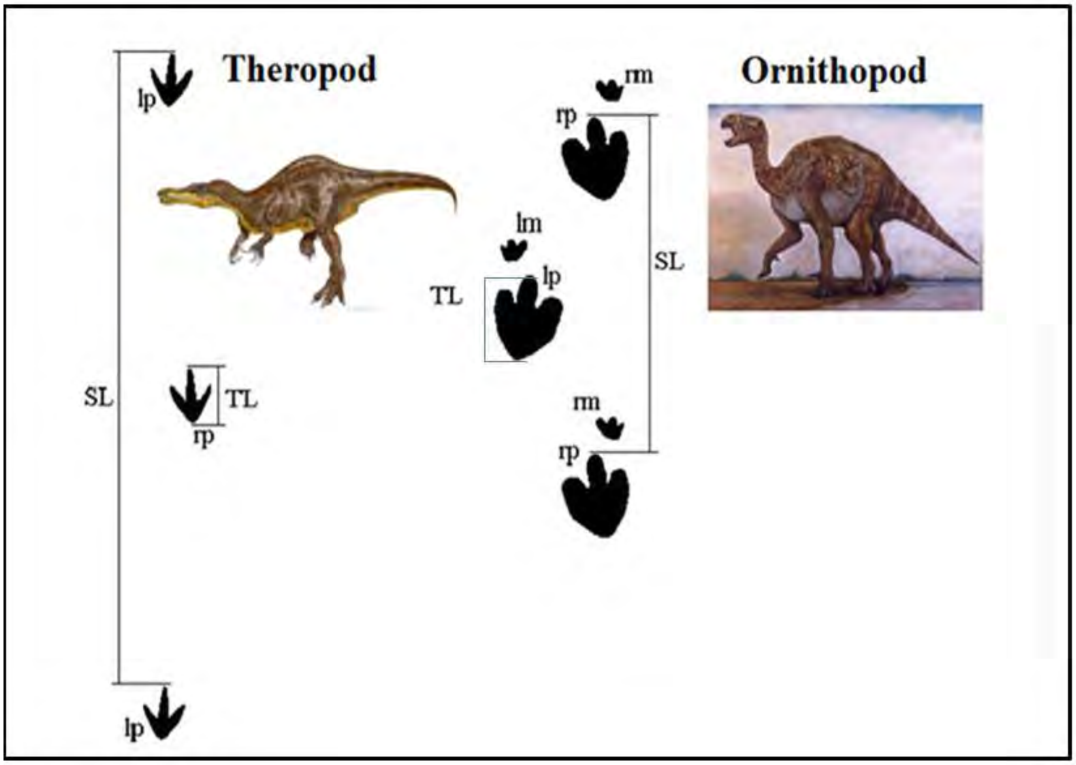
Q7. Based on Alexander's data, are you convinced that there is a linear relationship between an animal's dimensionless speed and the animal's relative stride length? What about based on your own data? Why or why not?

Q8. In Alexander's data, the best fit line that passes through his data points has the equation $\boldsymbol{y = 1.1x + 1}$, where $\boldsymbol{y}$ is relative stride length, and $\boldsymbol{x}$ is dimensionless speed. Rearrange this equation to solve for dimensionless speed in terms of relative stride length.

Q9. What is the value of the y-intercept of Alexander's best fit line? From this value, what general statement can be made about an animal's relative stride length, relative to speed?

- Find the two reproductions of dinosaur tracks In Figure 6 on the following page. The first set of tracks was left by a theropod (a member of a group of large bipedal dinosaurs), and the second set was left by an ornithopod (an herbivorous "bird-footed" dinosaur; incidentally, they are not closely related to birds, as theropods are considered the ancestors of modern birds). These tracks have been scaled down to 1/50th of their original size. We can use these tracks to determine the relative stride lengths of the dinosaurs that left them. However, in order to estimate the speed at which the dinosaurs traveled, we will also need to know the leg lengths of the dinosaurs. *Although there is no way to know exactly how long their legs were, it has been shown that, in general, a dinosaur's legs are about 4 times the length of its hind feet*. You can use this method of estimating leg length to determine the dimensionless speed at which these dinosaurs traveled.

Figure 6. Tracks left by a theropod dinosaur (left) and an ornithopod dinosaur (right). Tracks are shown at 1/50th actual size. l = left, r = right, p = pes (hind foot), m = manus (hand / "front foot"), TL = track length, SL = stride length.



- In making your measurements of these tracks, it will be easiest to measure them in millimeters. However, remember that to calculate their speed, we should find the sizes of their feet and legs in meters, as all calculations must be done in terms of meters. Don't forget that this image is only 1/50th actual size! Also, remember 1 m = 1000 mm!

Q10. How long were the legs of each of these dinosaurs?

Q11. Based on the equation of your best fit line, what would you estimate the dimensionless speed of these dinosaurs to be? Based on Alexander's equation, what would you estimate the dimensionless speed of these dinosaurs to be?

Q12. Based on the equation of your best fit line, how fast would you estimate that these dinosaurs were traveling in meters per second? How fast would you estimate that they were traveling in miles per hour?

Q13. Using Alexander's equation, how fast would you estimate that they were traveling?

Q14. How does Alexander's best fit line compare to your best fit line? Can you think of any reasons that the two lines might differ?

Exercise 1e.2: Open-ended Exploration

Using the information you learned in the previous exercises, see if you can estimate the speeds at which other animals were moving by examining their tracks. Do some internet searches for images of animal tracks, as well as data on average foot and leg lengths of animals for which you may find track images. Better yet, be on the lookout for animal tracks in your own backyard, or in natural areas near where you live. Prepare and share with your class a brief presentation on the animal tracks you found, your estimate of the animal's speed, and a possible scenario of the activity that was taking place when the animal left the tracks!

NOTE: The tracks in this unit are cast from real animal tracks. However, in order to save space and materials, the arrangements of the tracks on the clay are not necessarily the arrangements in which they would be found in a natural setting. Another option for this exploration would be to do some research to try to find the general patterns in which tracks of the animals represented in this unit are made, as well as average distances between them. See what you can find out about how (and how fast) these animals move from the average characteristics of their tracks!

This exercise has been adapted from the following sources:

Caton, R. and Otts, C. 1999. Fossil footprints: How fast was that dinosaur moving? *The American Biology Teacher* 61(7):528-531.

Harwood, R. 2009. Dinosaur Trackways. 22 February 2010. *Black Hawk College*. Accessed 22 February 2010. <http://facweb.bhc.edu/academics/science/harwoodr/Geol101/Labs/DinosaurTracks/>.

Over, D. J. 1995. Determining dinosaur speed. *Journal of Geological Education* 43:207-211.

Exercise 2: The Scoop on Poop!

Tracks are one of the most obvious signs that an animal has been present. However, animals leave other signs, such as feces (droppings or poop) behind as well. Naturalists and animal trackers call natural animal droppings **scat**, and scientists who study animal droppings are called **scatologists**. It may seem strange to study animal poop, but there is an amazing amount of information that can be learned from it. By examining the shape, size, texture, contents, locations, and DNA of natural animal droppings which are found in the field, scientists can

- determine an animal's species,
- map the area over which the animal roams
- identify the foods that form the animal's diet
- determine the animal's health status
- identify relatives

Identifying scat is not as easy as identifying an animal's tracks because it is more variable. No two scats are exactly alike, and an individual's scat can change based on what or how much it is eating. There are, however, general characteristics of poop that can help us identify the kind of animal that left it. For example:

- Herbivores (animals which eat grass and other plant material) generally leave very smooth and rounded pellet-like scat, often with plant fibers visible.
- Carnivores (animals that eat other animals) often have hair or feathers in their scat because these materials are not digestible.
- Bird scat usually contains white material that is actually urine mixed with their poop (Their urine has less water than other animals and is excreted as uric acid, which is the white part).
- Omnivores (animals which eat a mixed diet) often have undigested seeds in their scat, which can even sprout and grow! In fact, omnivores (and herbivores) that eat fruit and seeds are often important dispersers of the seeds of many plants. Since omnivores also eat animals, as well, there may also be hair in their scat, as also seen in carnivores.
- Insectivores (animals which eat insects) usually have small, rough, and irregular-shaped pellets. Sometimes undigested bits of insect exoskeleton can be found in them.

In these exercises, you will examine real animal scat. You will learn how to identify scat, and what we can tell about an animal from its scat. Don't worry…the scat used in this exercise is completely clean and safe. The poop is first dried, then coated in plastic and then sealed in a plastic container. Nevertheless, please do not try to open the boxes that contain the scats!

Exercise 2a: Matching the Poop with the Pooper (*Grades K-2*)

Materials:

All of the scat samples

Laminated matching sheets depicting animals and their scats (These can also be found in *The Animal Book*)

Instructions:

- Lay the laminated matching sheets face up.
- Match each scat sample with the picture that goes with it.
- See which animal left the poop!

Exercise 2b: Using a key to identify animal scat (*Grades 3-12*)

Materials:

All of the scat samples

Scat identification key

Instructions:

- Use the identification key to determine what kind of animal left each scat.
  (There is an explanation of how to use a dichotomous key in **Exercise 1c.**)
- Write down which animal you think left each scat (the scats are lettered)
- Check your answers using the answer sheet for Exercise 2b at the end of this book, or using *The Animal Book.*

The Backyard Naturalist Key to Animal Scats

1a. Scat is made up of smooth rounded pellets..Go to 2
1b. Scat is not made up of smooth rounded pellets ....Go to 3

2a. Scat pellets are oblong (longer in one direction) ....Go to 4
2b. Scat pellets are nearly spherical (ball-shaped) ....Eastern Cottontail
3a. Scat has a patch of white material...Go to 5
3b. Scat has no patch of white material ....Go to 6

4a. Scat pellets are larger than 1.5 cm ....Elk
4b. Scat pellets are smaller than 1.5 cm...White-tailed Deer

5a. Scat is like pebbles 1-3 cm in size ....Wild Turkey
5b. Scat is sausage-shaped with a grassy texture................................ Canada Goose

6a. Scat is made of irregular pellets less than 1 cm .... Little Brown Bat
6b. Scat is larger than 1 cm...Go to 7

7a. Scat contains animal hair ....Coyote
7b. Scat contains seeds...Striped Skunk

Exercise 2c: Grouping Scats by Animal Diet

Materials:

All of the scat samples

Instructions:

- Use the description of the general scat characteristics from the introduction to group the scats by the diet types of the animals that left them.
- Check your answers using either the answers for Exercise 2c at the end of this book, or in *The Animal Book*.

Exercise 3: Getting to Know the Animals (*Grades 3-12*)

Now that you are familiar with the animal tracks and scats in this box, let's learn some things about the animals that made them.

NOTE TO TEACHERS: Before beginning this game, place all of the tracks and scats in a location easily accessible for student observation.

Materials:
Entire set of animal tracks cast in resin
Entire set of preserved animal scat samples
Set of game cards

- Divide into groups of around 4 students each.
- Each group should receive a deck of cards, with a pawprint design on the back of each card.
- Each group should randomly determine an order in which students will take their turns.
- Shuffle the deck of cards.
- On your turn, draw a card from the top of the deck. This card will be labeled with the class, order, family, habitat, or diet of an animal.
- On a piece of paper, write down the information from your card.
- Next, go to the station where the teacher has placed all the animal track and scat samples.
- On your paper, beside the information you just wrote down from your card, write down the letter of a track or scat sample that you think comes from an animal that matches the information on this card. Make sure you indicate whether you selected a track or a scat.
- Play then continues, with each other student in your group doing the same on their turn.
- NOTE: Some cards will have more than one animal that corresponds to them, and individual animals will be represented by more than one card! You may write down the same track or scat sample for more than one card that you draw.
- The game ends when all cards in the deck have been drawn.
- Consult the answers in *The Animal Book* (near the end of this workbook).

- Scores can then be tallied, by giving each member of your group one point for each card they correctly matched to a track or scat sample.
- The student in each group with the most points wins!
- If you like, play the game as many times as time allows. This will help you in learning more about the many various animals presented in this unit!

******* <u>NOTES FOR TEACHERS:</u> *******

- For non-readers, the pictures on the cards can be used to facilitate this game.
- Strategically, since there are more taxonomy (class, order, & family) cards, these cards present opportunities for more points, thereby motivating students to learn the taxonomy in order to get more points!
- Sometimes, distinction between habitat or diet types (aquatic versus semi-aquatic, carnivore/herbivore versus omnivore) can be somewhat subjective. Encourage friendly discussion where lines between habitat/diet types may not be very distinct when it comes time to award points in the game. As the teacher, you should play the role of arbiter/judge if necessary.
- **Alternate Rules:** Below are some alternative rules that you may wish you use for this card game.
    1. Since some cards may represent more than one animal, teachers may wish to allow students to list as many track/scat samples as they can that they think are represented by the cards that they draw. This places less emphasis on taxonomy, and evens the importance of learning each of the aspects (taxonomy, diet, & habitat) of each animal in this unit. As a further variant, to discourage "cheating" by listing all the specimens for each card, in order to get all possible points, students could be assessed a one-point penalty for each incorrect answer at the end of the game.
    2. You may also wish to allow students to play as pairs within their groups, to facilitate discussion amongst students on the characteristics of the animals.
- For younger students, or for less detailed taxonomic learning, teachers may wish to have students in each group exclude the family-level taxonomy cards from the game. Just be sure they put these back in the bag with the other cards when they are finished with the game!

Exercise 4: Birdsongs and Things That Go Bump in the Night

We humans are visually oriented, and depend on our eyes to gather information about our surroundings. Good naturalists, however, use all of their sensory organs to identify animals. In particular, they use their ears. Because birds are frequently hidden in foliage, one of the best ways to identify them is by listening for their songs. Other animals are **nocturnal**, and thus are only active at night when it is too dark to see them. We can also use our ears to identify these nocturnal animals by the strange noises they make in the dark. It may seem spooky outside at night because we can't see what's around us, but if we learn to use the sounds animals make to identify them, the night can be fun instead. In these exercises, we will listen to recordings of the songs and the calls of birds and night animals so that we can learn to identify these animals by the sounds they make. The picture identification guides will be helpful, because since they show the animals' names and pictures, you can learn to associate the noises and songs with the animals that make them.

Exercise 4a: How many different birds do you hear? (*Grades K-2*)

Materials: *Birdsongs and Things That Go Bump in the Night* audio CD
Picture ID guide to birds (found on page 83 of this book)
CD Player

Instructions:

- Cue up track 1 on the CD and listen to the instructions.
- Go to track 27.
- Listen to the recording of the first group of birds.
- How many different kinds of birds did you hear in the track?
- Find the answer on the next track (28).
- Repeat the process for each of the groups included on the CD (tracks 29-40).

Exercise 4b: Identifying individual birds (*Grades 3-12*)

Materials: *Birdsongs and Things That Go Bump in the Night* audio CD
Picture ID guide to birds (found on page 83 of this book)
CD Player
Pencil and paper

Instructions:

- Listen to track 1 and 2 on the CD.
- Listen to track 3 and commit the songs you hear to memory.
- Complete the practice quiz found on track 4.
- Complete the quiz found on track 5.

You have now completed the first session.

- Repeat the above steps involving a learning session, a practice quiz and a quiz for sessions 2 (tracks 6-8) and 3 (tracks 9-11). Write down your answers and check them on the answer sheet for **Exercise 3b.**
- **BIG CHALLENGE:** At the end (track 12), there is a review quiz (Super Solver Quiz) involving all of the bird songs you have learned on this CD.
- Check your answers against the answer key for the super solver quiz on the answer sheet for **Exercise 4**.

Exercise 4c: Identifying birds in groups (*Grades 3-12*)

Materials: *Birdsongs and Things That Go Bump in the Night* audio CD
Picture ID guide to birds (found on page 83 of this book)
CD Player
Pencil and paper

Instructions:

- When you feel confident in your ability to identify individual bird songs, see if you can identify the calls of specific bird species from a group of many different bird species calling at the same time.
- Find Track 13 on the CD.
  This is a recording of a mixed group of bird species calling at the same time.
- Write down the names of all the different birds you hear on the track.
- Move to the next track to learn the correct answer.
- Repeat these steps for a total of 7 sessions (tracks 13-26).

Exercise 4d: Sounds of the Night (*Grades K-12*)

Materials: *Birdsongs and Things That Go Bump in the Night* audio CD
Picture identification guide of night animals (p. XX in this boo)
CD Player
Pencil and paper

Instructions:

- Find track 41 on the CD and listen to 'Introduction to Night Sounds'.
- Listen to the explanation of this exercise on track 42. Your goal is to learn to identify the calls of the frogs, birds, and insects that call at night. You will also learn to discriminate between the calls made by these three groups of nocturnal animals.

The recordings on subsequent tracks contain representative calls from each of the three groups.

- Listen to the frog calls on track 43 until you feel confident that you can discriminate between them.
- Complete the two frog call quizzes on tracks 44 & 45
- Check your answers under **Answers for Exercise 4d: Frog Quizzes.**
- Repeat this process for night bird calls on tracks 46-48
- Check your answers under **Answers for Exercise 4d: Night Bird Quizzes.**
- Listen to the two insects calls on track 49.
- Complete the quiz on discriminating between the calls of the three types of animals on track 51.
- Check your answers under **Answers for Exercise 4d: Type.**
- Complete the Super Solver Quiz on track 50, in which you are asked to identify the animal making each call.
- Check your answers under **Answers for Exercise 4d: Species.**

Exercise 4e: Visualizing Bird Songs (*Grades 7-12*)

Materials:

blank index cards
colored pencils
Birdsongs and Things That Go Bump in the Night audio CD

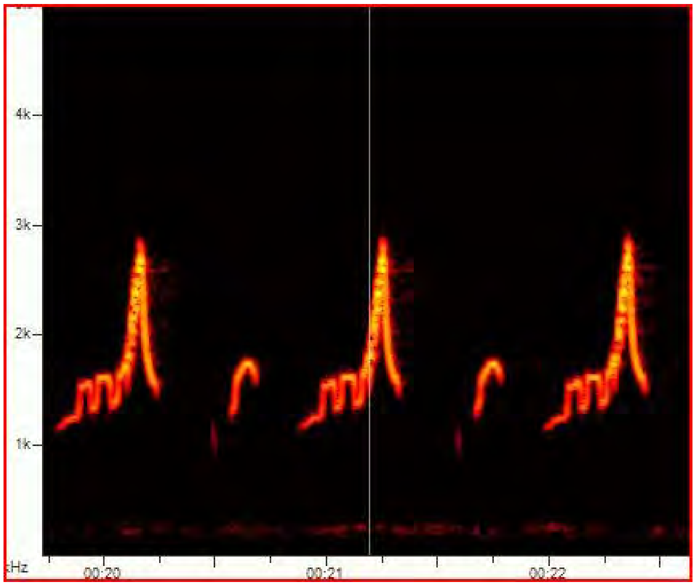
In previous exercises, we learned to identify animal sounds by listening to them again and again. In this exercise, we will learn to visualize bird songs. We will start by drawing our own pictures of bird songs, and then we will learn how scientists visualize bird songs. Visualizing bird songs will help us to notice the features that distinguish them, and thus improve our ability to recognize them in the future.

- Take out a blank index card and the colored pencils.
- Listen to the recording of the Whippoorwill's call on track 46.
- Try to draw a picture of the Whippoorwill's call.
- What features of the call were you able to record? Did you represent the call's length, loudness, and pitch? If so, how?
- Compare your drawing with that of another student. How are they similar? How are they different? Whose drawing is the best?

Scientists use pictures called spectrograms to visualize bird songs. A spectrogram is much like a piece of sheet music, in that time is recorded along the horizontal axis, and pitch is recorded along the vertical axis. In addition, spectrograms use color to record loudness. The colored curves you see in a spectrogram represent sounds. **Higher curves represent higher sounds, longer curves represent longer sounds, and more intensely colored curves represent louder sounds.**

- Look at the spectrogram of the Whippoorwill's call on the next page. Is it anything like the picture that you drew?

Figure 1: A spectrogram of the call of a Whippoorwill (*Caprimulgus vociferus*).



- Now that you are familiar with spectrograms, try to draw spectrograms of the bird songs on tracks 3, 6, and 9. Remember that pitch is recorded along the y-axis, and time along the x-axis. Also note that although the Whippoorwill's call is a simple melody, many birds will sing multiple notes at the same time. If a bird sings more than one note at once, then the spectrogram will look like a stack of curves instead of a single curve.
- On each track, you will hear the name of the bird that is about to sing. Record the bird's name on the back of an index card.
- On the front of the index card, draw a spectrogram of the bird's song.
- Once you have drawn all of the birds' songs, find a partner.
- Shuffle your index cards and show the spectrograms to your partner one at a time.
- See if he or she can guess the name of the birds by looking at your spectrograms.
- Then switch roles and see if you can guess the birds' names by looking at your partner's spectrograms.
- Finally, turn to the next page and compare the actual bird song spectrograms with the ones that you drew.

Figure 2: Spectrogram of a the call of a White-breasted Nuthatch (*Sitta carolinensis*).

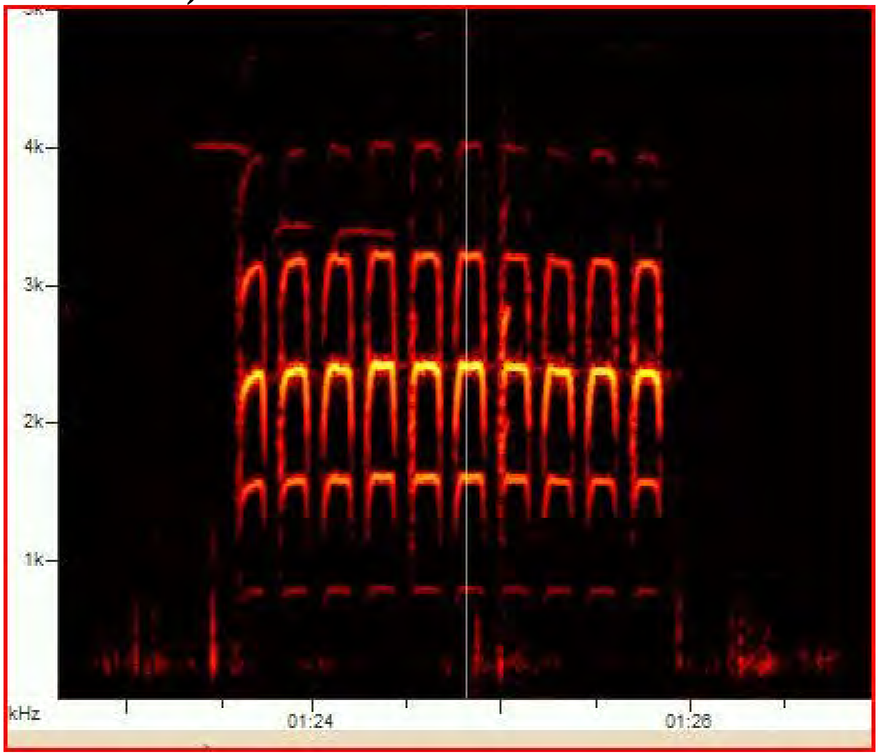


Figure 3: Spectrogram of the song of a Wood Thrush (*Hylocichla mustelina*).

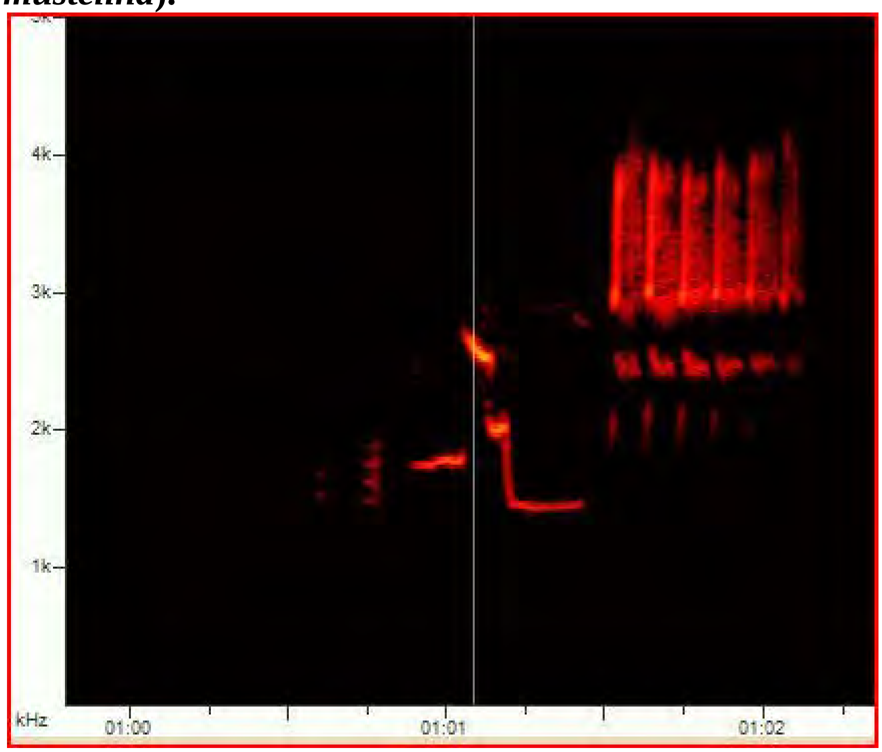


Figure 4: Spectrogram of a Northern Cardinal's song (*Cardinalis cardinalis*).

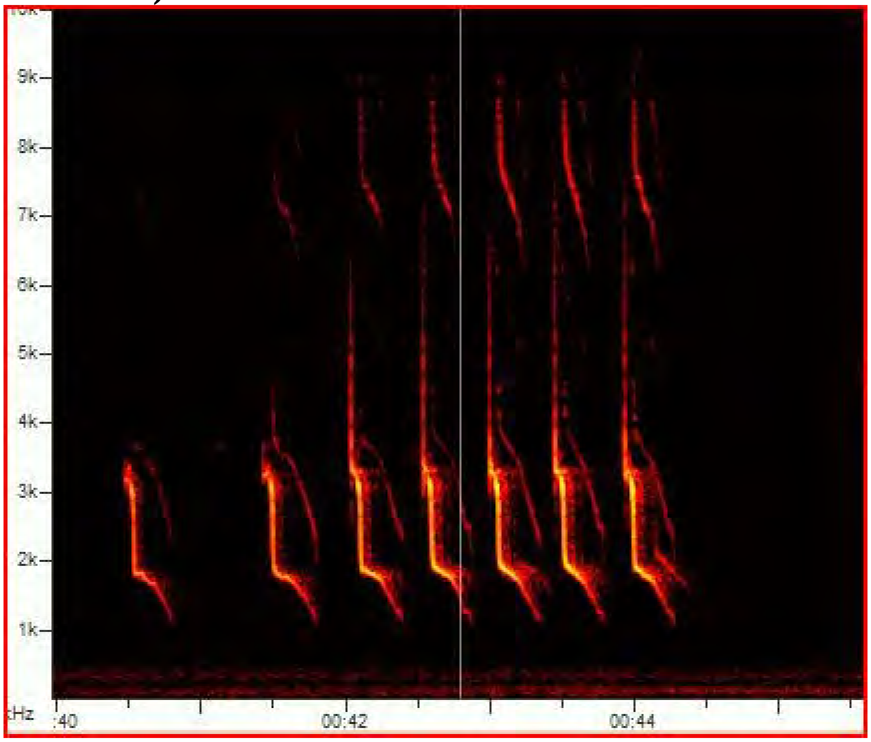


Figure 5: Spectrogram of the song of a Mourning Dove (*Zenaida macroura*).

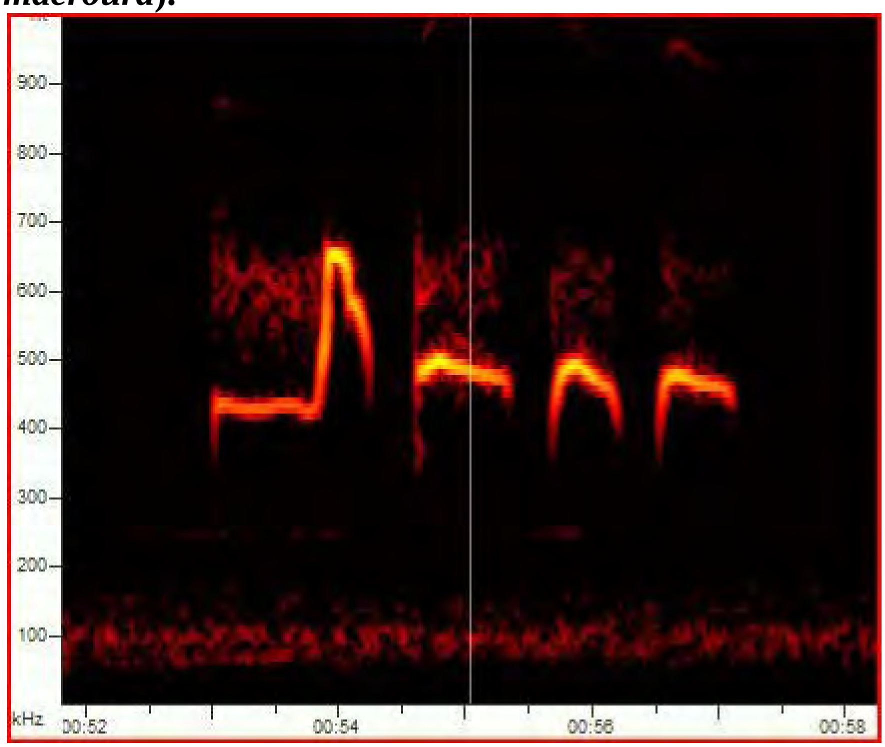
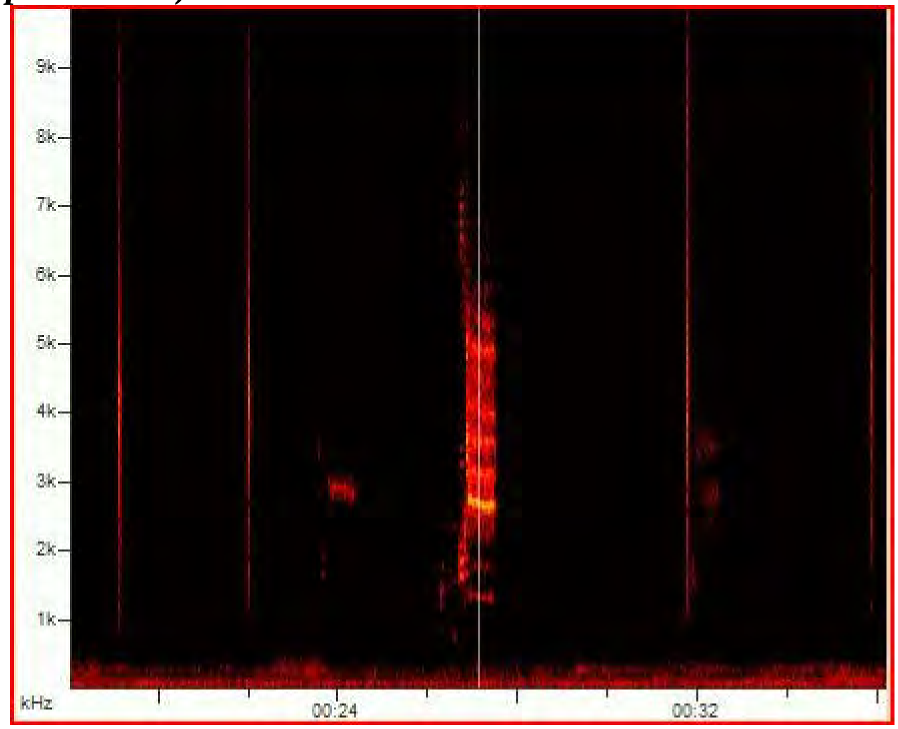


Figure 6: Spectrogram of the call of a Red-winged Blackbird (*Agelaius phoenicius*)



Exercise 4f: The Science of Sound (*Grades 7-12*)

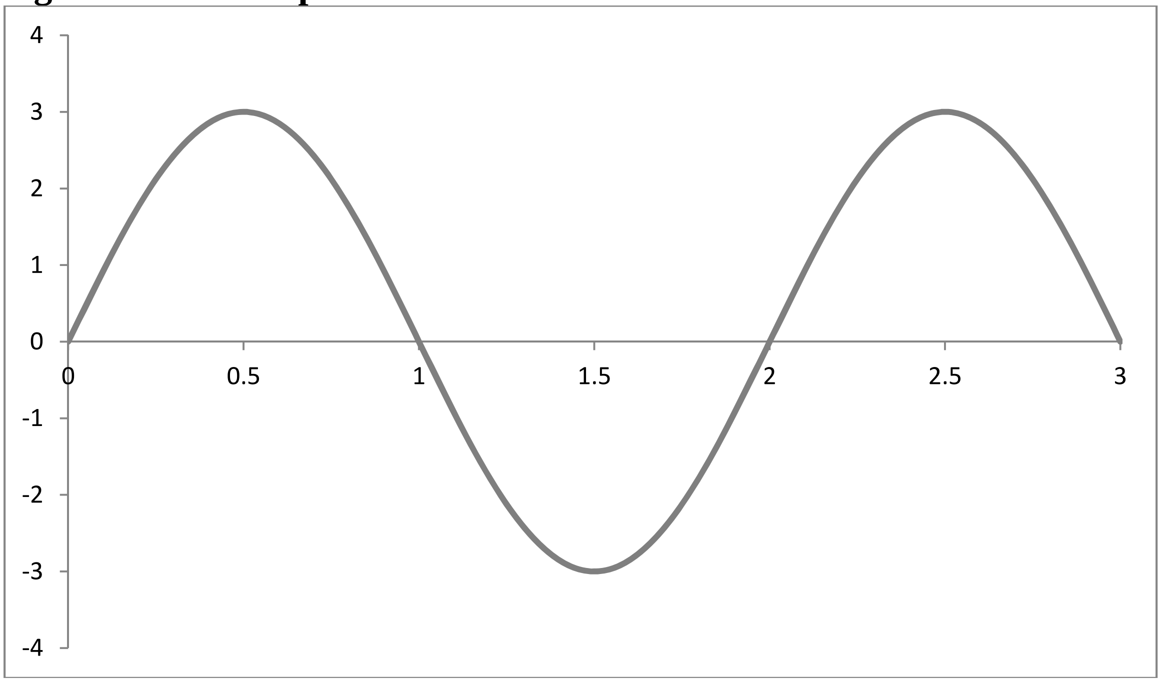
Wherever we go, there are lots of very different sounds all around us. From the alarm clock that may wake you up in the morning, to the rumbling engine of the school bus, to the shouts of your friends on the playground at recess, all sounds, as different as they may be, are formed in exactly the same way: by the movement or vibration of objects, particularly molecules of air. A sound is formed when something causes molecules of air to strike one another. When this happens, the molecules that strike one another continue to bump into and strike other nearby molecules, passing this movement or vibration along like a sort of chain reaction. As molecules are knocked towards other molecules, bringing them closer together, this creates areas of higher density of the air, in a process known as **compression**. However, once the molecules collide, and bounce off of each other, they get farther apart, creating regions of lower air density, which is a process known as **rarefaction**. Basically, as molecules of the air are compressed, they are then afterward **rarefied**, but which knocks them closer to other air molecules, again causing compression. Because of this, the molecules of air travel along in a cycle of compression and rarefaction, moving in a **wave**.

Sound can also be transmitted through other **media** (singular = **medium**), such as solids or liquids. However, there have to be molecules present to bump into one another to carry the sound wave along. Therefore, in a vaccuum, such as in space, sound cannot be transmitted.

Bird songs are transmitted through the air in exactly the same way, by waves consisting of regions of low pressure, or **rarefaction**, and regions of high pressure, or **compression**. Your ear is adapted to detect these changes in pressure.

A wave can be described by its period, amplitude, and frequency. Look at the plot of the pressure wave below. Pressure is measured along the y-axis and time is measured along the x-axis. The **period** of a travelling wave is the time between two successive peaks of the wave. The period of this wave is 2. The **amplitude** of a wave is the height of the wave's peaks. The amplitude of this wave is 3. The **frequency** of a travelling wave is the number of periods per unit time. As a result, the frequency is the reciprocal of the period. The frequency of this wave is ½.

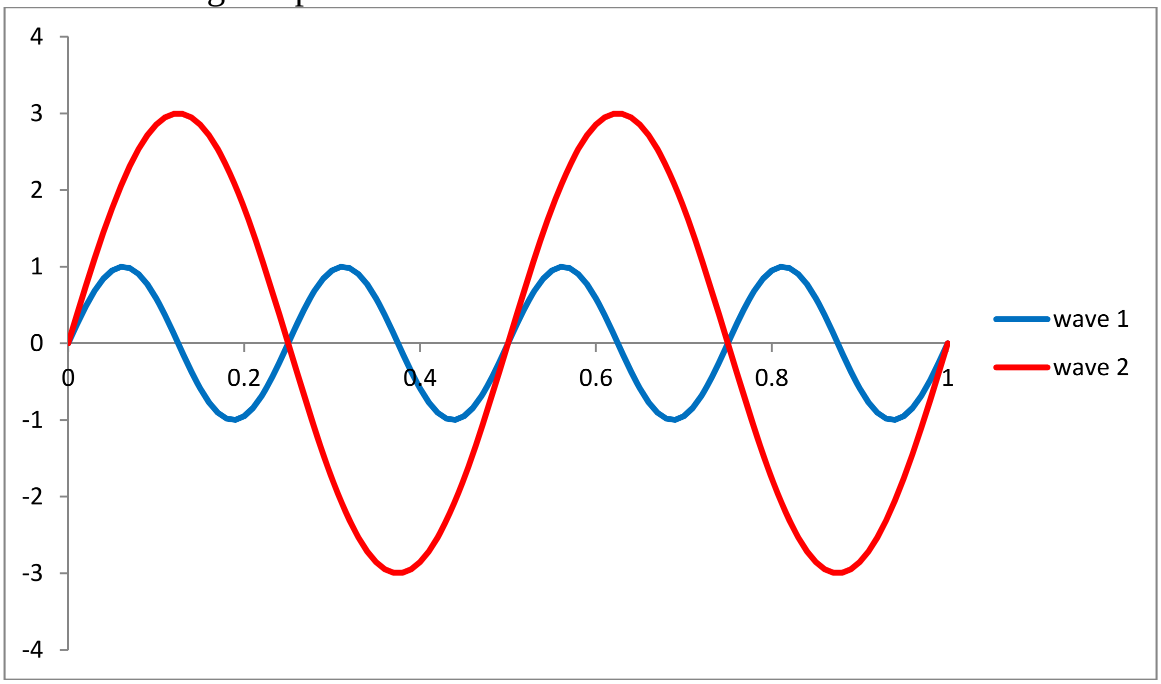
Figure 1: Plot of a pressure wave



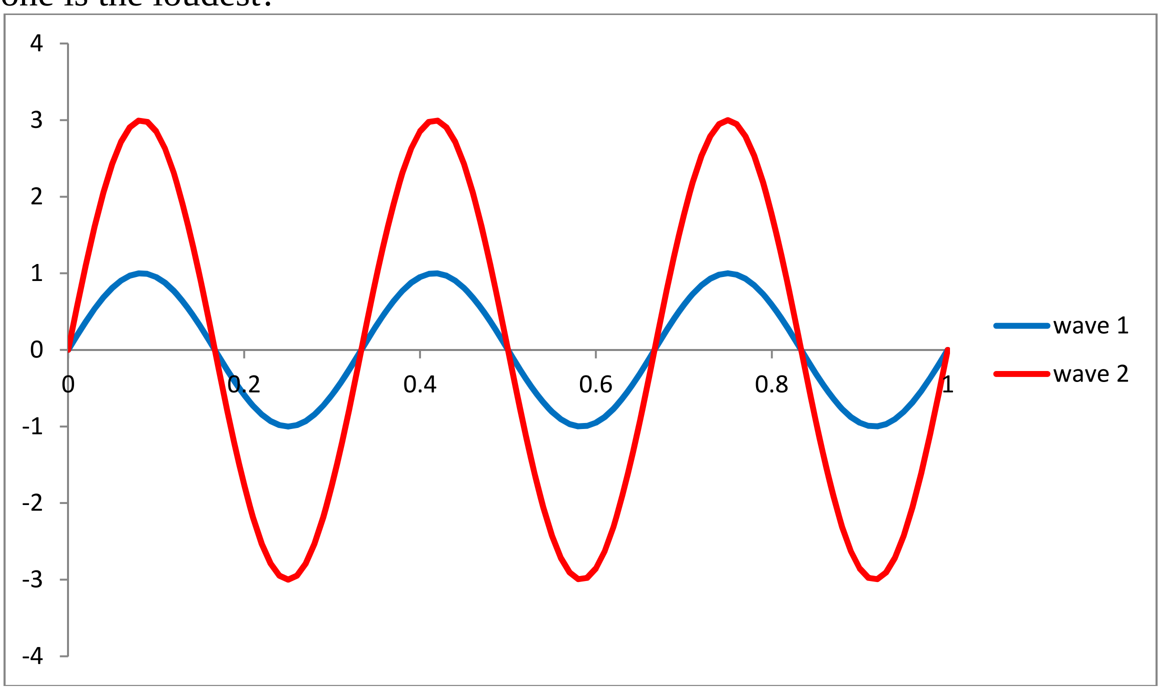
The amplitude and frequency of a pressure wave determine how the wave sounds. The frequency of the wave determines the pitch of the sound: the greater the frequency, the higher the pitch. The wave's amplitude and frequency both play a role in determining the loudness of the sound. The frequency of a pressure wave is important in determining its loudness because the human ear is more sensitive to certain frequencies than others. For example, a very high frequency wave, like that produced by a dog whistle, is inaudible to the human ear. However, if two pressure waves have the same frequency, then the wave with the greatest amplitude will sound the loudest.

Scientists usually measure the frequency of sounds in units known as **hertz** (**Hz**). A hertz is defined as one vibration or cycle per second. In other words, sounds with higher frequencies represent more rapid cycles of compression and rarefaction, or in other words, quicker vibration of molecules. Different species have differing capabilities of detecting sounds of particular frequencies. For example, people can hear sounds with frequencies ranging from 20 to 20,00 hertz, which is a rather large range. However, some animals, such as bats, dogs, dolphins and whales, and many others, can hear sounds with much higher frequencies. In fact, quite a few species communicate with one another using sounds that lots of other animals can't even hear!

Q1. What are the frequencies of the sound waves pictured below? Which one has the highest pitch?



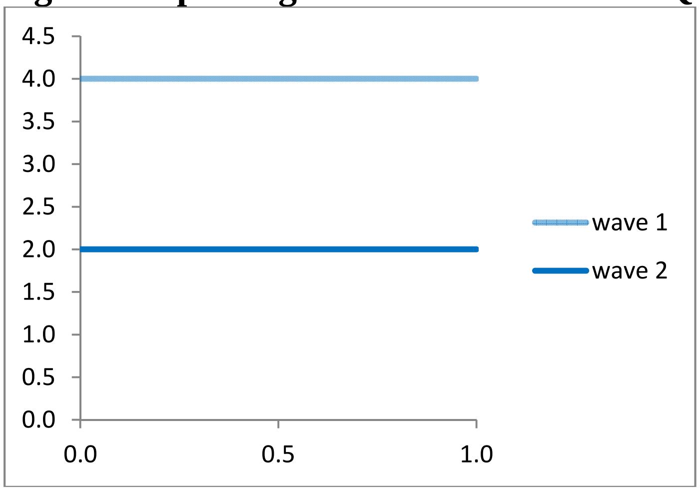
Q2. What are the amplitudes of the sound waves pictured below? Which one is the loudest?



How spectrograms are made

The **spectrogram** of a pressure wave is a plot of the wave's frequency through time. Wave frequency is plotted on the y-axis. Time is plotted on the x-axis. In a spectrogram, wave amplitude is represented by color: the greater the amplitude of the wave, the more intense the wave's color.

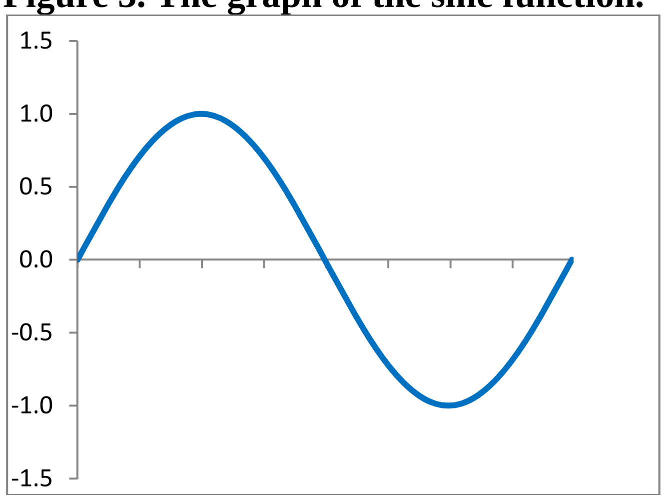
Figure 2: Spectrogram of the waves from Q1.



Q3. Draw the spectrograms of wave 1 from Q1 and wave 2 from Q2 on the same graph.

The sine function provides us with a mathematical representation of a wave. The waves that we have looked at so far are called **sinusoidal** waves, because they are the graphs of sine functions. For example, Figure 1 shows the graph of the function $\boldsymbol{y = 3\sin(\pi x)}$.

Figure 3. The graph of the sine function.



We can use the sine function to construct a simple wave with any frequency and amplitude that we want. In fact, the graph of the function

$$\boldsymbol{y = a\sin(b2\pi x)}$$

is a wave with amplitude *a* and frequency *b*.

Q5. What is an equation for a wave with frequency $\mathbf{7}$ and amplitude $\boldsymbol{\frac{1}{2}}$?

Q6. What is an equation for a wave with frequency $\boldsymbol{\frac{3}{\pi}}$ and amplitude $\boldsymbol{\pi}$?

The waves that carry bird songs are much more complicated than any of the waves that we have looked at so far. For example, look at the intricate form of the Whippoorwill's waveform below. (A close up of the wave about the white line is also pictured on the following page so that you can more clearly see its peaks and valleys.)

Figure 4: The Whippoorwill's waveform.

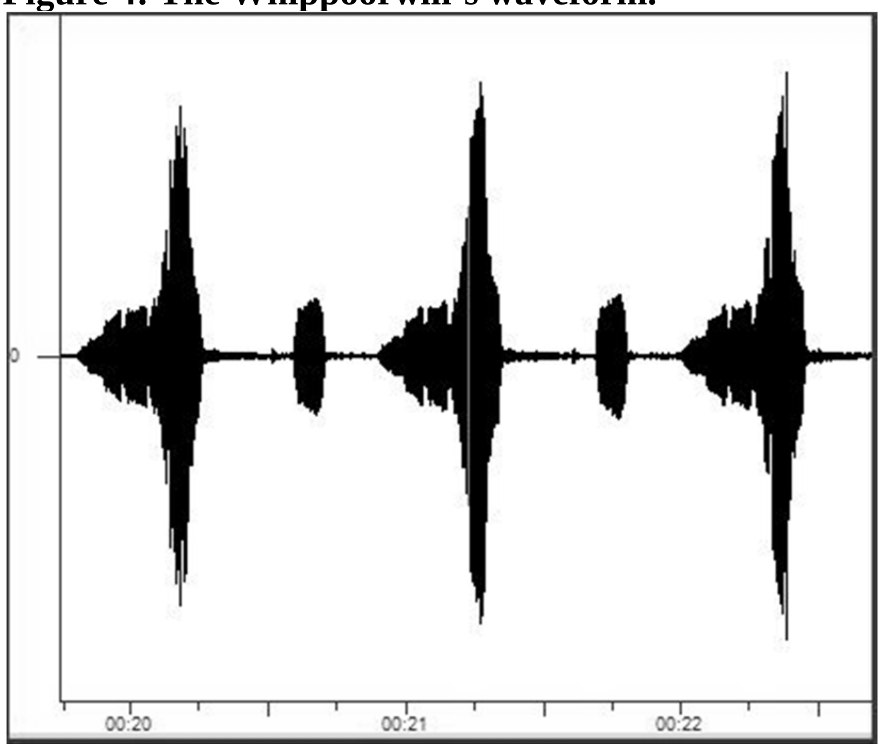
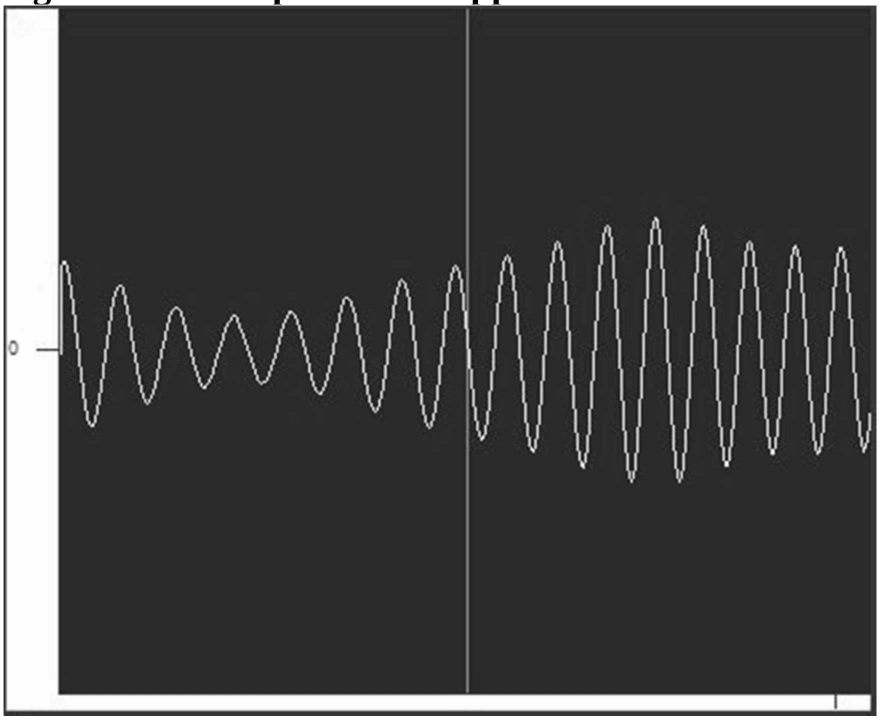


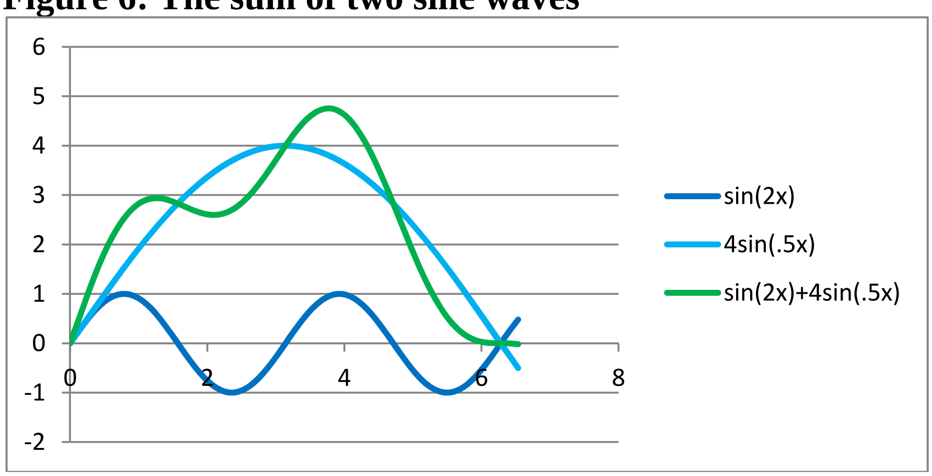
Figure 5: Close up of the Whippoorwill's waveform



Q7. What can you say about the amplitude of the Whippoorwill's waveform? Does it change over time, or is it fixed? What does your answer tell you about the sound of the Whippoorwill's call? How would your answer be represented on a spectrogram?

The equation of a complicated wave like this is actually the sum of many different sine functions with different amplitudes and frequencies. Special computer software can decompose complicated waves like this into their simple sinusoidal components. The figure below shows how two sine waves can combine the form a more complicated third wave. The individual sine waves are plotted in shades of blue, their sum is plotted in green.

Figure 6: The sum of two sine waves

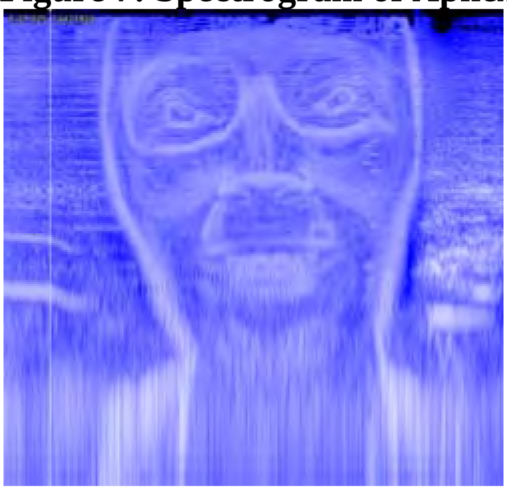


Once the simple waves that make up a more complicated wave have been found the sound spectrogram is generated by plotting the frequencies of the component waves against time.

Q8. Draw the spectrogram of the green wave from Figure 6. Check your answer under Answers to Exercise 4f.

Clever people have used these ideas to write music so that the spectrogram of the music appears as a sound. Figure 7 shows the spectrogram of a song called “Mathematical Equation” that was written by the musician Aphex Twin.

Figure 7: Spectrogram of Aphex Twin’s “Mathematical Equation”



<u>This exercise is adapted from the following source:</u>

McLinn, C. 2010. "Exploring Sound Activity -- Celebrate Urban Birds". Cornell Lab of Ornithology. Cornell University. Accessed 08 June 2010. <http://www.birds.cornell.edu/celebration/resources-for-celebrating/exploring-sound-1/>

THE ANIMAL BOOK

Biology in a Box

Unit 7: Backyard Naturalist

ANIMAL TRACK IDENTIFICATION SHEETS

Biology in a Box

Unit 7: Backyard Naturalist

Striped Skunk

Canada Goose

Bullfrog

Eastern Cottontail

Cougar

Raccoon

Mink 	**River Otter** 	**Great Blue Heron** 
Muskrat 	**Virginia Opossum** 	**Eastern Chipmunk** 

American Crow

Mallard Duck

White-tailed Deer

Common Snapping Turtle

Eastern Gray Squirrel

Red Fox

ANIMAL SCAT IDENTIFICATION SHEETS

Biology in a Box

Unit 7: Backyard Naturalist

Poop Sheet 1

White-Tailed Deer

Canada Goose

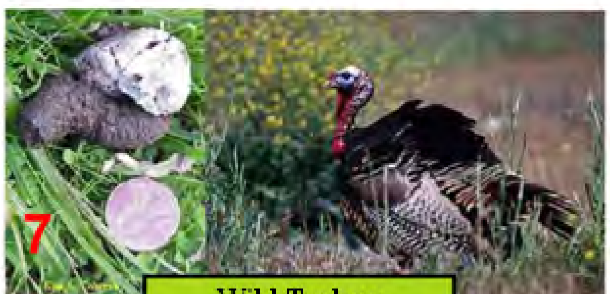
Coyote

Little Brown Bat

Poop Sheet 2

Elk

Striped Skunk



Wild Turkey

Eastern Cottontail

ANIMAL FACT SHEETS

Biology in a Box

Unit 7: Backyard Naturalist

Bullfrog (*Rana catesbeiana*)

Adult

Tadpole

Class: Amphibia (Amphibians)

Order: Anura (frogs & toads)

Family: Ranidae (true frogs)

Habitat: Aquatic/semi-aquatic (near and in ponds, lakes, streams, etc.)

Diet: Carnivore (insects, worms, & other small animals, including other frogs)

Comments: Females can lay up to 20,000 eggs in a filmy mass. The eggs hatch into tadpoles, and may take up to 3 years to mature before they metamorphose into adult frogs.

Common Snapping Turtle (*Chelydra serpentina*)

Class: Reptilia (reptiles)

Order: Testudines (turtles & tortoises)

Family: Chelydridae (snapping turtles)

Habitat: Aquatic (ponds, lakes, streams, estuaries)

Diet: Omnivore (invertebrates, fish, frogs, reptiles, birds, mammals, aquatic plants)

Comments: Snapping turtles are famous for the speed and power with which they can grab their prey (or a finger). A related species, the alligator snapping turtle (*Macrochelys temminckii*) lures animal prey near its powerful jaws with a worm-like projection on its tongue. Common snappers can reach 75 pounds, while alligator snappers can grow in excess of 200 pounds!

Mallard
(*Anas platyrhynchos*)

Class: Aves (birds)

Order: Anseriformes (waterfowl)

Family: Anatidae (ducks, geese, & swans)

Habitat: Semi-aquatic (wetlands - near ponds/lakes; riparian areas - near rivers & streams)

Diet: omnivore (aquatic plants, seeds, snails, insects, frogs)

Comments: This duck has adapted well to living around humans. Like many birds, the male is brightly colored to attract females, while the female is more camouflaged. Females typically lay 8-13 eggs during nesting season. Ducklings can immediately swim and catch food on their own, but typically remain with their mother for protection.

Canada Goose
(*Branta canadensis*)

Class: Aves (birds)

Order: Anseriformes (waterfowl)

Family: Anatidae (ducks, geese, & swans)

Habitat: Semi-aquatic (wetlands - near ponds/lakes; riparian areas - near rivers & streams)

Diet: Herbivore/slightly omnivorous (mostly grass & grains, but occasionally take insects or small fish)

Comments: This migratory bird is commonly seen along North American waterways. They are easily recognized not only by their distinctive black and white heads, but also by their loud honking calls.

Great Blue Heron
(*Ardea herodias*)

Class: Aves (birds)

Order: Ciconiiformes (wading birds)

Family: Ardeidae (herons)

Habitat: Semi-aquatic (wetlands - near ponds/lakes; riparian areas - near rivers & streams)

Diet: Carnivore (small fish, but also amphibians, reptiles, small birds, mammals, & aquatic invertebrates)

Comments: These tall wading birds usually forage while standing in water. When they spot prey, they lean slowly forward, arching their long necks before quickly grabbing the potential food item with their sharp, slender beaks. Though they typically hunt alone, they nest in large, noisy colonies of 50-500 individuals.

Wild Turkey (*Meleagris gallopavo*)

Class: Aves (birds)

Order: Galliformes (gamefowl)

Family: Phasianidae (pheasants, partridges, chickens, turkeys)

Habitat: Terrestrial (deciduous & mixed forests, forest edges, agricultural areas)

Diet: Omnivore (grasses, leaves, roots, seeds, fruits, insects, spiders, snails, small amphibians)

Comments: Male turkeys ("toms") can be distinguished from females by the presence of a long fleshy wattle that hangs from the beak, as well as a "beard" of feathers on the chest. Though they may look clumsy, Wild Turkeys can fly up to 89 km/hr (55 mph) in short bursts!

American Crow
(*Corvus brachyrhynchos*)

Class: Aves (birds)

Order: Passeriformes (perching birds)

Family: Corvidae (crows, ravens, jays, & relatives)

Habitat: Terrestrial/arboreal (forests, open areas, towns & cities)

Diet: Omnivore (invertebrates, dead animals, seeds, bird eggs & hatchlings, fish, grains, mice, frogs, fruits & nuts)

Comments: These intelligent birds are often attracted to shiny objects that they put in their nests. They often mimic the vocalizations of other birds & animals. Crows were once incorrectly assumed to judge & kill flock members that misbehaved. For this reason, a group of crows became known as a "murder."

Elk (*Cervus canadensis*)

Class: Mammalia (mammals)

Order: Artiodactyla (even-toed ungulates)

Family: Cervidae (deer & relatives)

Habitat: Terrestrial (forests & forest edges)

Diet: Herbivore (grasses, plants, leaves, and bark)

Comments: The elk is one of the largest species of deer in the world, and one of North America's largest mammals. The Eastern elk, a subspecies once found in Tennessee, is now extinct, but reintroduction of a related subspecies by conservation groups has been fairly successful in restoring these large herbivores to forests in the Appalachian region.

White-Tailed Deer
(*Odocoileus virginianus*)

Fawn

Adult Male

Class: Mammalia (mammals)

Order: Artiodactyla (even-toed ungulates)

Family: Cervidae (deer & relatives)

Habitat: Terrestrial (forests & grasslands)

Diet: Herbivore (twigs, leaves, acorns, grasses, fruit)

Comments: Deer are shy, and are usually seen at dusk or early morning. The males have antlers, and fight with each other to keep a harem of females. The white "flag" on the underside of the white-tailed deer's tail is used to communicate an alarm signal to other deer when a predator has been sighted, to help groups of deer stay together, and to let a predator know that it has been spotted.

Coyote
(*Canis latrans*)

Class: Mammalia (mammals)

Order: Carnivora (carnivores)

Family: Canidae (dogs & their relatives)

Habitat: Terrestrial (many various habitats all over North America)

Diet: Carnivore (small mammals, birds, reptiles, deer, insects, carrion)

Comments: Though they often catch & consume smaller prey on their own, coyotes hunt larger prey (such as deer & elk) in packs, and have been documented to pursue such prey for up to 21 hours, typically covering an average of 4 km (2.5 miles) during a night's hunt.

Red Fox
(*Vulpes vulpes*)

Class: Mammalia (mammals)

Order: Carnivora (carnivores)

Family: Canidae (dogs & their relatives)

Habitat: Terrestrial (found in a variety of habitats, from forests to marshes to tundras)

Diet: Omnivore (invertebrates, fruits, rodents, rabbits, birds, eggs, amphibians, reptiles, & fish)

Comments: Red foxes actually come in a variety of colors, and some change fur color in the winter. They have been hunted for their fur, and are often regarded as pests (though they rarely hunt livestock). In fact, in Japan, they are revered for preying on rodents and insects that destroy crops.

Mountain Lion or Cougar (*Puma concolor*)


Class: Mammalia (mammals)

Order: Carnivora (carnivores)

Family: Felidae (cats)

Habitat: Terrestrial (woodlands, rainforests, deserts)

Diet: Carnivore (deer are their most important prey, but they also eat other mammals, birds, & insects)

Comments: These large cats are important predators in many food chains. They are rarely seen, as they are shy and avoid people. They are thought to have been extirpated from most of the U.S., with the exception of Florida, but many reports have been submitted throughout the eastern states.

Striped Skunk
(*Mephitis mephitis*)


Class: Mammalia (mammals)

Order: Carnivora (carnivores)

Family: Mephitidae (skunks)

Habitat: Terrestrial (forests, fields, & urban areas)

Diet: Omnivore (eggs, mice, berries, grubs)

Comments: Skunks are best known for their ability to spray a foul-smelling secretion from their anal glands. This chemical defense is highly effective at deterring predators, and has even been known to drive away bears. Skunks can spray this compound with a great degree of accuracy up to about 5 m (15 feet)!

River Otter
(*Lontra canadensis*)


Class: Mammalia (mammals)

Order: Carnivora (carnivores)

Family: Mustelidae (weasels & their relatives)

Habitat: Aquatic/Semiaquatic (wetlands - near ponds/lakes; riparian areas - near rivers & streams)

Diet: Carnivore (fish, frogs, crayfish)

Comments: Highly intelligent and playful, these relatives of weasels are active during the day. They build dens along riverbanks, and are excellent swimmers. They are capable of diving up to 17 m (55 feet), and swimming as far as 0.4 km (0.25 miles) underwater. Both of these skill come in handy for catching their aquatic prey.

Mink
(*Mustela vison*)

Class: Mammalia (mammals)

Order: Carnivora (carnivores)

Family: Mustelidae (weasels & their relatives)

Habitat: Semiaquatic (wetlands - near ponds/lakes; riparian areas - near rivers & streams)

Diet: Carnivore (muskrats & other rodents, frogs, fish, birds, & snakes)

Comments: Minks are well known for their fine fur. In the wild, they are territorial and aggressive. They are ferocious hunters, often attacking prey their own size or even larger. They are also good swimmers, which helps them efficiently catch their often aquatic prey.

Raccoon
(*Procyon lotor*)

Class: Mammalia (mammals)

Order: Carnivora (carnivores)

Family: Procyonidae (raccoons, coatis, ringtails, & relatives)

Habitat: Terrestrial/Arboreal (deciduous & mixed forests, agricultural areas, & occasionally cities)

Diet: Omnivore (fruit, berries, grains, eggs, poultry, vegetables, nuts, molluscs, fish, insects, rodents)

Comments: Due to the markings around their eyes, raccoons are often referred to as "masked bandits." Raccoons are nocturnal, & sometimes steal their dinners from garbage containers in urban areas. They do best in forested areas, however, as they depend heavily on trees to climb when they feel threatened.

Little Brown Bat (*Myotis lucifugus*)

Class: Mammalia (mammals)

Order: Chiroptera (bats)

Family: Vespertilionidae (common bats/vesper bats)

Habitat: Terrestrial/Arboreal (hollow trees, attics, barns, & caves)

Diet: Insectivore (mostly insects with an aquatic life stage, such as mosquitoes)

Comments: Little Brown Bats catch insects with their wingtips, then scoop them into a pouch formed by their tails, and eat them in flight. Like many bats in the eastern U.S., Little Brown Bat populations are declining due to white nose syndrome, a fungal disease that kills bats. The fungus can clearly be seen on the bat in the image above.

Virginia Opossum (*Didelphis virginiana*)

Class: Mammalia (mammals)

Order: Didelphimorphia (New World opossums)

Family: Didelphidae (New World opossums)

Habitat: Arboreal/Terrestrial (forests, open woods, rural & urban areas)

Diet: Omnivore (fruit, nuts, dead animals, insects, birds, small animals)

Comments: The Virginia Opossum is North America's only marsupial (animals in which the mother carries the babies in a pouch). They may act dead ("play possum") when threatened, though they may also show their teeth and hiss loudly. Their prehensile tails assist them in climbing, and are sometimes used to carry small objects.

Eastern Cottontail (*Sylvilagus floridanus*)

Class: Mammalia (mammals)

Order: Lagomorpha (rabbits, hares, & pikas)

Family: Leporidae (rabbits & hares)

Habitat: Terrestrial (prefer brushy areas)

Diet: Herbivore (vegetation, twigs, & bark)

Comments: Rabbits are typically active during evening and early morning, and take shelter in burrows & brush piles. Females can have up to four litters of 4-7 young per year. Lagomorphs (and some rodents) produce two kinds of poop. They typically eat the softer form (known as cecotropes) to extract all possible nutrients from their hard-to-digest herbaceous diet.

Muskrat
(*Ondatra zibethicus*)

Class: Mammalia (mammals)

Order: Rodentia (rodents)

Family: Cricetidae (hamsters, voles, lemmings, New World rats & mice)

Habitat: Semi-aquatic (wetlands - near ponds/lakes, riparian areas - near rivers/streams)

Diet: Herbivore (aquatic vegetation)

Comments: Muskrats have webbed hind feet, and are strong swimmers. Like beavers, they build houses with underwater entrances out of sticks. They are active at night (nocturnal), but also near dawn and dusk (crepuscular). Muskrats are important prey for many predatory mammals, birds, & reptiles.

Eastern Grey Squirrel
(*Sciurus carolinensis*)

Class: Mammalia (mammals)

Order: Rodentia (rodents)

Family: Sciuridae (tree, ground, & flying squirrels; chipmunks, marmots, & prairie dogs)

Habitat: Arboreal/Terrestrial (forests, rural & urban areas)

Diet: Herbivore (mostly nuts & seeds)

Comments: Grey squirrels are most commonly seen foraging for nuts on the ground. They cache (store) food for the winter either in their home trees, or buried nearby in scattered locations. Like many squirrels, they communicate with other squirrels with a complex system of vocalizations & posturing, including flicks of their fluffy tails.

Eastern Chipmunk
(*Tamias striatus*)

Class: Mammalia (mammals)

Order: Rodentia (rodents)

Family: Sciuridae (tree, ground, & flying squirrels; chipmunks, marmots, & prairie dogs)

Habitat: Terrestrial (forests, brushy areas, rural & urban gardens & lawns)

Diet: Mostly herbivorous (seeds, fruits, nuts), but also consumes some insects

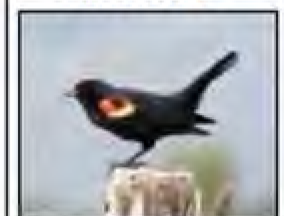
Comments: These small mammals live in underground burrows where they store food. They are most active and breed in warm months, and sleep through most of the winter (hibernate).

PICTURE GUIDE TO NIGHT BIRDS AND ANIMALS

For use with the *Birdsongs & Things that Go Bump in the Night* Audio CD

Biology in a Box

Unit 7: Backyard Naturalist

Group 1	**Eastern Wood-Pewee**  *Contopus virens*	**American Crow**  *Corvus brachyrhynchos*	**Carolina Chickadee**  *Poecile carolinensis*	**White-breasted Nuthatch**  *Sitta carolinensis*	**Wood Thrush**  *Hylocichla mustelina*
Group 2	**Carolina Wren**  *Thryothorus ludovicianus*	**House Finch**  *Carpodacus mexicanus*	**Red-tailed Hawk**  *Buteo jamaicensis*	**Red-winged Blackbird**  *Agelaius phoeniceus*	**American Robin**  *Turdus migratorius*
Group 3 **Northern Cardinal**  *Cardinalis cardinalis*	**Downy Woodpecker**  *Picoides pubescens*	**American Goldfinch**  *Spinus tristis*	**Mourning Dove**  *Zenaida macroura*	**Blue Jay**  *Cyanocitta cristata*	**Northern Mockingbird**  *Mimus polyglottos*

FROGS & TOADS

Spring Peeper
Pseudacris crucifer

Chorus Frog
Pseudacris sp.

Bullfrog
Rana catesbeiana

American Toad
Bufo americanus

NIGHT BIRDS

Barred Owl
Strix varia

Great Horned Owl
Bubo virginianus

Eastern Screech Owl
Megascops asio

Whippoorwill
Caprimulgus vociferus

Common Nighthawk
Chordeiles minor

NIGHT INSECTS

Field Cricket
Gryllus sp.

Katydid
Family Tettigoniidae

ANSWER SHEETS

Answers for Exercise 1: Who Walked Here?

"Super Solver" question:

What besides animal type can we learn from examining the tracks an animal makes?

1. Approximately how long ago the animal made the track. As a track ages, its edges become less sharp. This, of course, is affected by weather.
2. One can tell how big an animal is, as a heavier animal will have a deeper print, and a larger animal a larger print. Depth, of course, will be affected by how soft the ground is at the time the animal traveled across it.
3. We can get some information about how fast the animal was traveling by the spacing and pattern of the footprints.
4. By following a track, one can also get some idea of the home range of the animal.

Answers for Exercise 1b: Measure those Tracks

Q1. In general, how does the length of an animal's back foot compare to the length of its front foot? Is one foot longer usually longer or are they about the same length? Explain how the data in your table support your answer.

In general, the length of the back foot is usually greater than the length of the front foot. We know this is true because well over half of the ratios (back foot length)/ (front foot length) are greater than one.

Q2. In general, how does the width of an animal's back foot usually compare to the width of its front foot? Is one foot longer usually wider or are they about the same width? Explain how the data in your table support your answer.

In general, the width of the back foot is about the same as the width of the front foot. We know this is true because about well over half of the ratios (back foot length)/ (front foot length) are very close to one.

Q3. In general, how does the area of an animal's back foot usually compare to the area of its front foot? Does one foot longer usually have a larger area or are they about the same size? Explain how the data in your table support your answer.

In general, the area of the back foot is usually greater than the area of the front foot. We know this is true because well over half of the ratios (back foot area)/ (front foot area) are greater than one.

Q4. Can you think of some biological reasons for the trends in foot length ratios, foot width ratios, and foot area ratios that you observed? Think about how animals use their feet and how the functions of back feet may differ from those of front feet. You might start by thinking about your own back feet (feet) and front feet (hands).

Many animals such as rabbits have powerful back legs that they use to propel themselves forward. It makes sense that these animals would have larger back feet to support these powerful legs, and to increase the leverage the animal gets when it pushes against the ground. Also, many animals use their front feet to perform functions that require precision. For example, raccoons use their front feet to open containers and to grasp their food. Small feet are better suited to these precise tasks. Finally, many animals can improve their vantage point by standing up on their back feet. Larger back feet provide an animal with more stability when it wants a better view of its environment.

Q5. Can you think of any biological reasons why the trends you observed in foot length ratios might differ from those you observed in foot width ratios? Hint: what direction do most animals move in?

Most animals move primarily in a forward direction. Longer feet provide an animal with more leverage when it is moving forward. When an animal is moving forward wider feet might actually slow the animal down by creating drag.

Exercise 1c Answer Key

Track ID	Animal
A	White-tailed Deer
B	Red Fox
C	Mallard Duck
D	Common Snapping Turtle
E	Bullfrog
F	River Otter
G	Cougar
H	Great Blue Heron
I	Eastern Cottontail
J	American Crow
K	Raccoon
L	Opossum
M	Eastern Grey Squirrel
N	Canada Goose
O	Eastern Chipmunk
P	Muskrat
Q	Striped Skunk
R	Mink

Answers to Exercise 1e: Fossil Footprints – How Fast Was That Dinosaur Moving?

Q1. If you measure and record each student's height, weight, and age in your class, will you have created a set of bivariate data? Why or why not? What are the variables in this data set?

No, because we have recorded the value of *three* variables, height, weight, and age. If we measure more than two parameters, we are dealing with a multivariate (many variable) data set.

Q2. Does it look like there is a linear relationship between foot length and leg length? Why do you think this is the case?

Yes, because all of the data points fall close to the line.

Q3. Does it look like there is a linear relationship between the variables shown in Figure 3 below?

No, because the data points are not close to the best fit line. Though the variables do appear to be positively correlated, the relationship between them is not linear. In fact, the relationship shows an exponential increase in Variable 2 relative to Variable 1.

Q4. What does it mean for a number to be dimensionless? Explain why the dimensionless speed is indeed dimensionless.

A dimensionless number has no units. The dimensionless speed has no units because the units of the numerator and denominator cancel each other out.

Q5. Based on the slope of your line, do relative stride length and dimensionless speed appear to be positively or negatively correlated? Is this similar to the pattern noted by Alexander?

Based on Alexander's data, relative stride length and dimensionless speed are positively correlated. Students' results should show a similar trend, in that the faster one moves, the longer the relative stride length.

Q6. How well does your best fit line appear to fit the data? Are the points clustered close to the line?

Students' answers to this question may vary, since they collected their own data for this experiment. However, since only three students are in each group, most of the data points collected should fall fairly close to the best fit line within a group. When the entire class's data are compiled, the relationship should still look fairly linear, though there may be considerable scatter about the best fit line.

Q7. Based on Alexander's data, are you convinced that there is a linear relationship between an animal's dimensionless speed and the animal's relative stride length? What about based on your own data? Why or why not?

Students' answers to this question may vary based on their own experimental data, but Alexander's data should be fairly convincing that a significant linear relationship between dimensionless speed and relative stride length exists.

Q8. In Alexander's data, the best fit line that passes through his data points has the equation y = 1.1x + 1, where y is relative stride length, and x is dimensionless speed. Rearrange this equation to solve for dimensionless speed in terms of relative stride length.

Rearranging the equation of the best fit line expressing relative stride length (y) as a function of dimensionless speed (x), we obtain the following:

$$\boldsymbol{x = \frac{(y-1)}{1.1}}$$

Q9. What is the value of the y-intercept of Alexander's best fit line? From this value, what general statement can be made about an animal's relative stride length, relative to speed?

The y-intercept of the equation of Alexander's best fit equation is equal to a relative stride length of 1. Using the equation of the best fit line, dimensionless speed is only a positive value if relative stride length is greater than 1, or in other words, if an animal's stride length is longer than its leg length. Though it is possible to have a stride length less than one's leg length (you can try this yourself by taking very short, shuffling steps), such movement seems fairly inefficient, though of course, exceptions may exist in other animals.

Q10. How long were the legs of each of these dinosaurs?

In the scaled image, the track length of the theropod is approximately 0.9 cm long, and that of the ornithopod is about 1.3 cm long. Since the image is 1/50 actual size, the feet of the theropod would have been around 45 cm long, and those of the ornithopod, around 65 cm long. Since we mentioned earlier that dinosaurs' legs are generally 4 times the length of their feet, the theropod's leg would have been around 180 cm (1.8 m) long, and the ornithopod's leg would have been around 260 cm (2.6 m) long.

Q11. Based on the equation of your best fit line, what would you estimate the dimensionless speed of these dinosaurs to be? Based on Alexander's equation, what would you estimate the dimensionless speed of these dinosaurs to be?

Students' answers will vary based on the equations of their best fit lines. However, using the scaled images and Alexander's equation, we can solve for their dimensionless speeds as follows:

Since Alexander's equation says that y = 1.1x +1, where ***y*** = relative stride length (which is equal to stride length/leg length), and ***x*** = dimensionless speed, we can solve for dimensionless speed in terms of relative stride length:

$$x = \frac{(y - 1)}{1.1}$$

After calculating the stride lengths of the dinosaurs (accounting for the scale in the figure), the stride length of the theropod is approximately equal to 4.75 m, and the stride length of the ornithopod is approximately equal to 2.7 m. Since we already calculated the leg lengths of these dinosaurs in Q7, we can now calculate their relative stride lengths. The relative stride length of the theropod would be equal to its stride length (4.75 m) divided by its leg length (1.8 m), or approximately 2.64. The relative stride length of the ornithopod would be equal to its stride length divided by its leg length (2.7 m/2.6 m), which is approximately equal to 1.03. Now we can simply use these values to solve for the dimensional speeds of each of these dinosaurs using the above equation. The theropod would thus have had a dimensionless speed of approximately 1.49. The ornithopod would have had a dimensionless speed of about 0.03.

Q12. Based on the equation of your best fit line, how fast would you estimate that these dinosaurs were traveling in meters per second? How fast would you estimate that they were traveling in miles per hour?

Again, this answer will vary based on the students' own best fit lines.

Q13. Using Alexander's equation, how fast would you estimate that they were traveling?

Given that we already know the relationship between dimensionless speed and speed:

$$\boldsymbol{dimensionless\ speed} = \frac{\boldsymbol{speed}}{\sqrt{(\boldsymbol{leg\ length} \times \mathbf{9.81}\ \boldsymbol{m/s^2})}},$$

we can rearrange this equation to solve for actual speed, as follows:

$$\boldsymbol{speed} = \boldsymbol{dimensionless\ speed} \times \sqrt{(\boldsymbol{leg\ length} \times \mathbf{9.81}\ \boldsymbol{m/s^2})}$$

Using this information, and the fact that we have already calculated the leg lengths and dimensionless speeds of each of the dinosaurs, we can substitute those values into the equation to solve for each dinosaur's actual speed. Remember, it is important that leg length be reported in meters! Using our results from earlier, we can calculate that the speed of the theropod was approximately 6.26 m/s, and that the ornithopod was travelling approximately 0.18 m/s. We can convert these values to miles per hour, since we know that there are

3600 seconds in an hour (60 seconds in each of 60 minutes), and that a mile is equal to 1609.344 meters, as follows:

$$\frac{\mathbf{6.26}\ \boldsymbol{meters}}{\boldsymbol{second}} \times \frac{\mathbf{3600}\ \boldsymbol{seconds}}{\mathbf{1}\ \boldsymbol{hour}} \times \frac{\mathbf{1}\ \boldsymbol{mi}}{\mathbf{1609.344}\ \boldsymbol{m}} \approx \mathbf{14.00}\ \boldsymbol{miles\ per\ hour}$$

Notice that an easy way to convert from one unit to another is to multiply by a system of ratios that are equal to 1 (3600 s = 1 hr; 1 mi = 1609.344 meters), so that all of the units (except for the units we want in our final answer) cancel out. Using the same method, we can calculate that the ornithopod was only travelling at about 0.40 mph, a rather leisurely stroll. The theropod, in comparison, was moving along rather quickly, but still not as fast as the fastest estimate (around 27 mph) for theropods!

Q14. How does Alexander's best fit line compare to your best fit line? Can you think of any reasons that the two lines might differ?

Student answers may vary. Some important considerations are the accuracy of student measurements, as well as the fact that their measurements were only of a relatively small sample size, and only using humans, as well as the fact that dinosaur morphology, such as musculature, may have imposed constraints different than those experienced by extant (currently living) animals today.

Answers for Exercise 2: The Scoop on Poop

Answers for Exercise 2b: Matching the Poop to the Pooper (Scat IDs)

Scat Letter	Figure #	Animal name
A	1	WHITE-TAILED DEER
B	5	ELK
C	7	WILD TURKEY
D	4	LITTLE BROWN BAT
E	2	CANADA GOOSE
F	3	COYOTE
G	6	STRIPED SKUNK
H	8	EASTERN COTTONTAIL

Answers for Exercise 2c: Animal Diets by Scat Type

Herbivores: White-tailed deer (A), Elk (B), Rabbit (H)
Carnivore: Coyote (F)
Omnivore: Striped Skunk (G)
Insectivore: Little Brown Bat (D)
Birds: Wild Turkey (C), Canada Goose (E)

Answers for Exercise 4: Birdsongs & Things That Go Bump in the Night

Exercise 4b: Answer Key to Backyard Bird Identification Quizzes

Group 1

Quiz 1	Quiz 2
1) White-Breasted Nuthatch	1) Wood Thrush
2) American Crow	2) Eastern Wood Pewee
3) Eastern Wood Pewee	3) White-Breasted Nuthatch
4) Wood Thrush	4) Carolina Chickadee
5) Carolina Chickadee	5) American Crow

Group 2

Quiz 1	Quiz 2
1) Red-Tailed Hawk	1) House Finch
2) American Robin	2) Red-Winged Blackbird
3) House Finch	3) Carolina Wren
4) Carolina Wren	4) American Robin
5) Red-Winged Blackbird	5) Red-Tailed Hawk

Group 3

Quiz 1	Quiz 2
1) Mourning Dove	1) Northern Mockingbird
2) Downy Woodpecker	2) Blue Jay
3) Northern Cardinal	3) American Goldfinch
4) Northern Mockingbird	4) Downy Woodpecker
5) American Goldfinch	5) Northern Cardinal
6) Blue Jay	6) Mourning Dove

Type Quiz and Super Solver Quiz

1) Mourning Dove	2) Northern Cardinal	3) Eastern Wood Pewee
4) Blue Jay	5) Red-Tailed Hawk	6) Carolina Chickadee
7) Red-Winged Blackbird	8) American Goldfinch	9) Northern Mockingbird
10) House Finch	11) White-Breasted Nuthatch	12) Carolina Wren
13) American Robin	14) Downy Woodpecker	15) Eastern Wood Pewee
16) Wood Thrush		

Exercise 4d: Key to Night Sounds Quizzes

Frog Calls

Quiz 1	Quiz 2
1) Bullfrog	1) Chorus Frog
2) Chorus Frog	2) American Toad
3) American Toad	3) Spring Peeper
4) Spring Peeper	4) Bullfrog

Night Bird Calls

Quiz 1	Quiz 2
1) Screech Owl	1) Barred Owl
2) Common Nighthawk	2) Whippoorwill
3) Barred Owl	3) Great Horned Owl
4) Great Horned Owl	4) Common Nighthawk
5) Whippoorwill	5) Screech Owl

Night Animals Quizzes for Tracks 50-51

1) Field Cricket (insect)
2) Bullfrog (frog)
3) Whippoorwill (bird)
4) Barred Owl (bird)
5) Spring Peeper (frog)
6) Chorus Frog (frog)
7) Screech Owl (bird)
8) Common Nighthawk (bird)
9) Katydid (insect)
10) Great Horned Owl (bird)

Answers for Exercise 4f: The Science of Sound

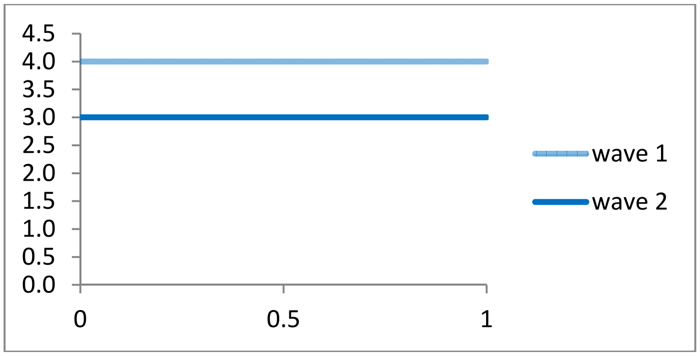
Q1. What are the frequencies of the sound waves pictured below? Which one has the highest pitch?

The frequency of wave 1 is 4. The frequency of wave 2 is 2. Wave 1 has the highest pitch.

Q2. What are the amplitudes of the sound waves pictured below? Which one is the loudest?

The amplitude of wave 1 is 1. The amplitude of wave 2 is 3. Wave 2 is the loudest.

Q3. Draw the spectrograms of wave 1 from Q1 and wave 2 from Q2 on the same graph.



Q5. What is an equation for a wave with frequency 7 and amplitude $\frac{1}{2}$?

$$y = \frac{1}{2} sin(14\pi x)$$

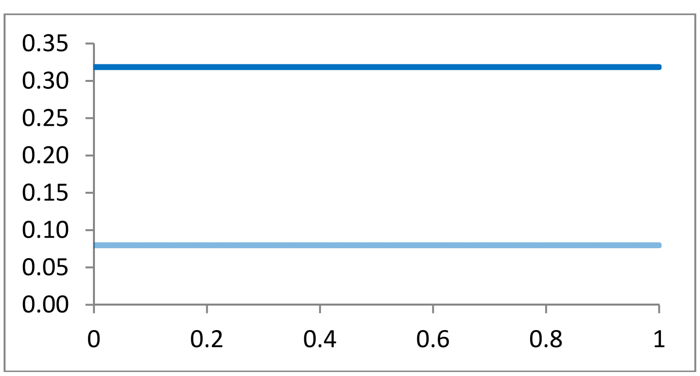
Q6. What is an equation for a wave with frequency $\frac{3}{\pi}$ and amplitude π?

$$y = \pi \sin(6x)$$

Q7. What can you say about the amplitude of the Whippoorwill's waveform? Does it change over time, or is it fixed? What does your answer tell you about the sound of the Whippoorwill's call? How would your answer be represented on a spectrogram?

The amplitude of the Whippoorwill's wave form changes over time. As a result, the volume of the Whippoorwill's call also changes. On a spectrogram, this changing amplitude would be represented by changes in color.

Q8. Draw the spectrogram of the green wave from Figure 6.



SUGGESTED READING

Grades K-3

Crinkleroot's Guide to Animal Tracking - Jim Arnosky
Wild Tracks!: A Guide to Nature's Footprints - Jim Arnosky
Footprints in the Snow - Cynthia Benjamin & Jacqueline Rogers (Illustrator)
Whose Footprint Is That? - Jacqui Brown
Poop: A Natural History of the Unmentionable - Nicola Davies & Neal Layton (Illustrator)
Around the Pond: Who's Been Here - Lindsay Barrett George
In the Snow: Who's Been Here? - Lindsay Barrett George
Follow Those Feet! (Dora the Explorer Ready-to-Read) - Susan Hall
Who Pooped in the Park? (Great Smoky Mountains National Park) - Steve Kemp & Robert Rath (Illustrator)
Whose Tracks are These? A Clue Book of Familiar Forest Animals - James Nail
Those Toes - Marie McLaughlin & Roni Rohr (Illustrator)
Big Tracks, Little Tracks: Following Animal Prints - Millicent E. Selsam & Marlene Hill Donnelly (Illustrator)

Grades 4-7

Tracks, Scats and Signs - Leslie Dendy
On Safari (Animal Trackers Around the World) - Tessa Paul
Down Under (Animal Trackers Around the World) - Tessa Paul
The Signs Animals Leave - Frank J. Staub
Land Predators of North America - Erin Pembrey Swan
Dinosaur Tracks - Kathelen Weidner Zoehfeld & Lucia Washburn (Illustrator)
Turtle Tracks - Sally Harman Plowden & Tee Plowden (Illustrator)

Grades 7+

Mammal Tracks & Sign: A Guide to North American Species - Mark Elbroch
Scats and Tracks of North America: A Field Guide to the Signs of Nearly 150 Wildlife Species - James Halfpenny & Todd Telander (Illustrator)
Animal Tracking Basics - Tiffany Morgan
Peterson Field Guide to Animal Tracks - Olaus J. Murie, Mark Elbroch, & Roger Tory Peterson
Tracking and the Art of Seeing: How to Read Animal Tracks and Sign - Paul Rezendes

All Ages

Track Pack: Animal Tracks in Full Life Size - Ed Gray & Decourcy L. Taylor (Illustrator)
Animal Tracks (Peterson FlashGuides) - Richard Philip Grossenheider, Olaus J. Murie, & Roger Tory Peterson (Editor)
Mammal Tracks and Scat: Life-Size Tracking Guide - Lynn Levine & Martha Mitchell (Illustrator)

Scientific Journal Articles (included on Teacher CD)

Alexander, R.M. 1996. Walking and running. *The Mathematical Gazette* 80(488):262-266.
Alexander, R.M. 1976. Estimating speeds of dinosaurs. *Nature* 261:129-130.
Greenleaf, S.S., S.M. Matthews, R.G. Wright, J.J. Beecham, & H.M. Leithead. 2009. Food habits of American black bears as a metric for direct management of human-bear conflict in Yosemite Valley, Yosemite National Park, California. *Ursus* 20(2):94-101.
Hass, C.C. 2009. Competition and coexistence in sympatric bobcats and pumas. *Journal of Zoology* 278(3):174-180.

LINKS

All About Birds – a great virtual field guide about North American birds from Cornell University's Laboratory of Ornithology; provides images, range maps, call audio, nest cams, and much more! http://www.allaboutbirds.org/

Animal Sign Experiment - A great basic of a project for students K-12 to gather data on animal signs in their own schoolyard! Presented by the St. Clair County Regional Office of Education in Illinois. http://web.stclair.k12.il.us/splashd/animale.htm

Animal Tracks and Sign - A blog by a tracker in upstate NY. Hasn't been updated in a while, but still gives good pictures of actual tracks and scats, including many animals also found in the southeastern US.
http://animaltracksandsign.blogspot.com/

Biology of Extinct Animals - Website on "the biomechanics of terrestrial locomotion" from John Merck at the University of Maryland's Department of Geology.
http://www.geol.umd.edu/~jmerck/bsci392/lecture11/lecture11.html

Bird Communication – Webpage on bird communication from Gary Ritchison at Eastern Kentucky University.
http://people.eku.edu/ritchisong/birdcommunication.html

EEK! Follow that footprint, paw print, hoof print - A short, but informative site from Wisconsin's Department of Natural Resources' Environmental Education for Kids! site.
http://www.dnr.state.wi.us/org/caer/ce/eek/nature/track.htm

eNature: ZipGuides (Mammal Tracks) - Great online field guide from eNature.com. Simply input your ZIP code to help you identify mammal tracks you might find in your area!
http://www.enature.com/zipguides/customguide.asp?guidetype=tracks

Horse Gaits Flipbooks - A great craft for younger students to explore the biomechanics of different horse movement patterns; part of the American Museum of Natural History's OLogy site.
http://www.amnh.org/ology/features/stufftodo_horse/horse_gaits.php?TB_iframe=true&height=500&width=800

Identifying and Preserving Wildlife Tracks - A site by Jon Boren with the College of Agricultural, Consumer, and Environmental Sciences at New Mexico State University. Gives info on how to preserve tracks found in the field, and has a list of additional reading.
http://cahe.nmsu.edu/pubs/_circulars/circ561.html

Keeping a Field Journal - Another OLogy website from AMNH; introduces younger students to the concept of keeping a field journal, an important tool for naturalists!
http://www.amnh.org/ology/features/stufftodo_genetics/fieldjournal.php?TB_iframe=true&height=500&width=600

National Wildlife Federation - Great website full of tons of information, including a section for kids, too! http://www.nwf.org/

Outdoor Action Guide to Animal Tracking - An excellent website from Rick Curtis with information taken from a workshop at Tom Brown's tracking school. Gives in-depth info on types of signs/tracks, movement patterns, aging tracks, and more!
http://www.princeton.edu/~oa/nature/tracking.shtml

Science Experiment – Making Sound Waves – This page, from Reeko's Mad Scientist Lab, gives more background information on the science of sound, as well as a simple experiment to illustrate the propagation of a sound wave, using only marbles.
http://www.reekoscience.com/Experiments/ExpSoundWaves.aspx

Tracks and Signs - A nice website with activities on collecting/preserving tracks, along with other activities. Also has a few links to other sites, as well as suggested reading.
http://www.concord.org/~btinker/guide/tracks/tracks_activities.html

Wild About Birds - a "virtual birding" site from the Illinois Natural history Survey.
http://www.inhs.uiuc.edu/resources/virtualbird/index.html