MANITOBA ENVIROTHON
SKILLS IN FIELD ECOLOGY

2021 EDITION

INTRODUCTION

"Tell me and I forget. Show me and I remember. Involve me and I understand."
John Gay

For any individual, whether they would like to work in the field of ecology, environmental sciences, or conservation following high school, considering a career that involves spending extensive time in natural areas, or a passion of nature and natural history, it is important to gain practical field skills. This training ranges from basic mathematical skills, how to identify species, mapping, to working in extreme environments. The skills outlined here will not only help students during *Manitoba Envirothon*, but add to their hands-on skills, which may transferable to many careers and hobbies.

The ***Skills in Field Ecology*** handbook intends to highlight and teach a variety of useful techniques. It is not meant to be an all encompassing list of all the skills required to succeed but a set up helpful tips and tools to help students succeed. Students will not be expected to memorize information from this book, but instead to use this resource to develop and improve their field skills, which are applicable to all *Manitoba Envirothon* disciplines.

BASIC DATA SKILLS

Many field skills involve using our analytical skills to translate empirical measurements we take in the field into useful metrics or measurements. It is important for any field ecologist to process basic math skills to ensure success in such endeavours! Although most of you may already be familiar with these techniques, we will work through some of these skills below.

MEAN, MEDIAN, AND MODE: MEASURES OF CENTRAL TENDENCY

Mean, median, and mode are three kinds of *averages*.

The *mean* is the *average* most people use, where you add up all the numbers and then divide by the number of numbers.

$$\text{Mean} = \frac{\text{sum of values}}{\text{number of values}}$$

The *median* is the *middle* value in the list of numbers. To find the *median*, your numbers have to be listed in numerical order from smallest to largest, so you may have to rewrite your list before you can find the median.

$$1, 3, 3, \mathbf{6}, 7, 8, 9$$

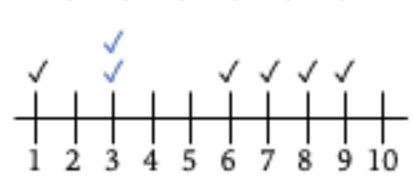
$$\text{Median} = \boldsymbol{6}$$

$$1, 2, 3, \mathbf{4}, \mathbf{5}, 6, 8, 9$$

$$\text{Median} = (4+5) \div 2 = \mathbf{4.5}$$

The *mode* is the value that occurs most often. If no number in the list is repeated, there is no *mode* for the list.

$$1, \mathbf{3}, \mathbf{3}, 6, 7, 8, 9$$



$$\text{Mode} = 3$$

Now, let us work through an example:

Data:

13, 18, 13, 14, 13, 16, 14, 21, 13

Mean: Add and then divide by the number of values (n=9):

$$(13 + 18 + 13 + 14 + 13 + 16 + 14 + 21 + 13) \div 9 = \mathbf{15}$$

Note that the *mean*, in this case, is not a value from the data. That is not uncommon! You should not assume that your mean will be one of your original numbers.

The *median* is the middle value, so first you need to rewrite the list in numerical order:

13, 13, 13, 13, 14, 14, 16, 18, 21

There are nine numbers in the list, so the middle one will be the 5th number:

13, 13, 13, 13, **14**, 14, 16, 18, 21

So the median is **14**.

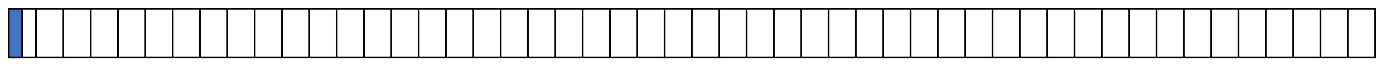
The mode is the number that is *repeated* more often than any other, so **13** is the mode.

mean: 15
median: 14
mode: 13

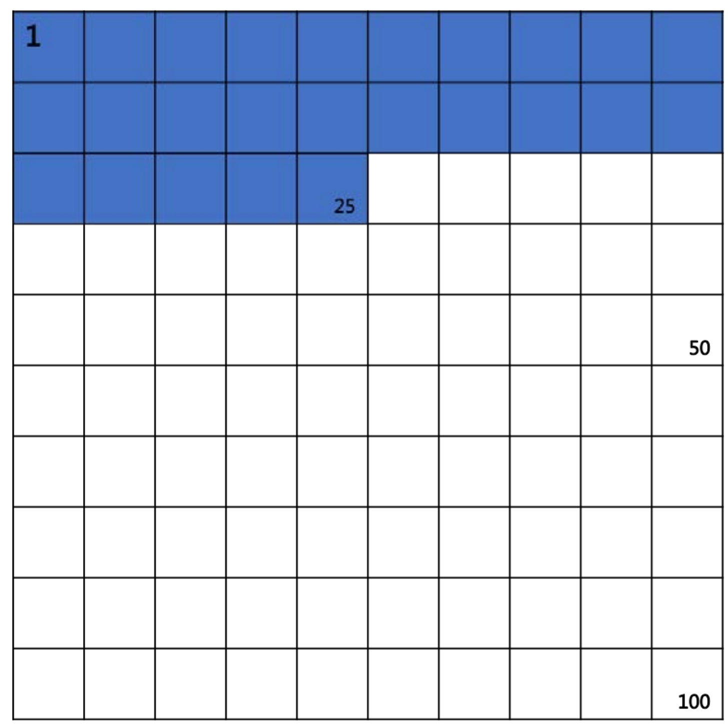
CALCULATE A PERCENTAGE

The term 'percent' literally means 'out of a hundred'. Percentages are used like fractions and decimals, as ways to describe *parts of a whole*. When you are using percentages, the whole is considered to be made up of a hundred equal parts. The symbol % is used to show that a number is a percentage.

One percent (**1%**) means 1 per 100.



1% of this line is shaded blue: it is very small isn't it?



25% means 25 per 100 (25% of this box is blue)

It is easy to work out the percentage when there are 100 individual 'things' making up the whole, as in the grid above. But what if we are trying to calculate the percentage of a number other than 100? In order to find a given percentages of a whole, work out the value of 1%, then multiply it by the percentage you need to find.

For example, percentage of 80 acres is covered by trees if 5 acres are covered?

$$\text{Percentage} = \frac{\text{5 acres covered}}{\text{80 acres total}} \text{ x } 100\% = 0.0625 \text{ x } 100\% = 6.25\%$$

Alternatively, how many acres is 35% of 80 total acres?

$$\frac{35\%}{100\%} \text{ x } 80 = 0.35 \text{ x } 80 = 28 \text{ acres}$$

To write a percentage as a decimal, simply divide it by 100. For example, 60% becomes 0.6, 15% becomes 0.15, and 3% becomes 0.03.

BEDMAS - ORDER OF OPERATIONS

Suppose you are asked to evaluate an expression that looks something like this

$$8 + 4 \times 3 \div 2 = ?$$

When an expression contains many operations, we must be careful of what order we do the operations in. For example, if we do all the operations as we would read them (from left to right), we would get the following:

$$\begin{aligned} 8 + 4 \times 3 \div 2 &= 12 \text{ x } 3 \div 2 \\ &= 36 \div 2 \\ &= 18 \end{aligned}$$

However, we will see why the correct answer is actually 14. We get the incorrect answer because the order of operations is **important**. BEDMAS is an acronym that reminds us of the correct order of operations:

Brackets	First Priority
Exponents	Second Priority
Division	Third Priority
Multiplication	Third Priority
Addition	Fourth Priority
Subtraction	Fourth Priority

BEDMAS tells us that brackets are the highest priority, then exponents, then both division and multiplication, and finally addition and subtraction. That means that we evaluate exponents before we multiply, divide before we subtract, etc. So going back to our example, we see that we made the *mistake of adding before dividing*. According to BEDMAS, division is a higher priority than addition. We also divided and multiplied in the expression. Should we multiply or divide first?

If an expression has two or more operations of the same priority, do those operations from left to right

So, let us try the calculation again:

$$8 + 4 \times 3 \div 2 = 8 + 12 \div 2$$
$$= 8 + 6$$
$$= 14$$

From BEDMAS, the division and multiplication must be done before addition. We also must multiply before dividing in this case because the multiplication sign comes first when we read the expression from left to right.

There is one other BEDMAS rule that should be remembered:

When dealing with brackets inside brackets (called nested brackets), evaluate what's inside the inner-most brackets first

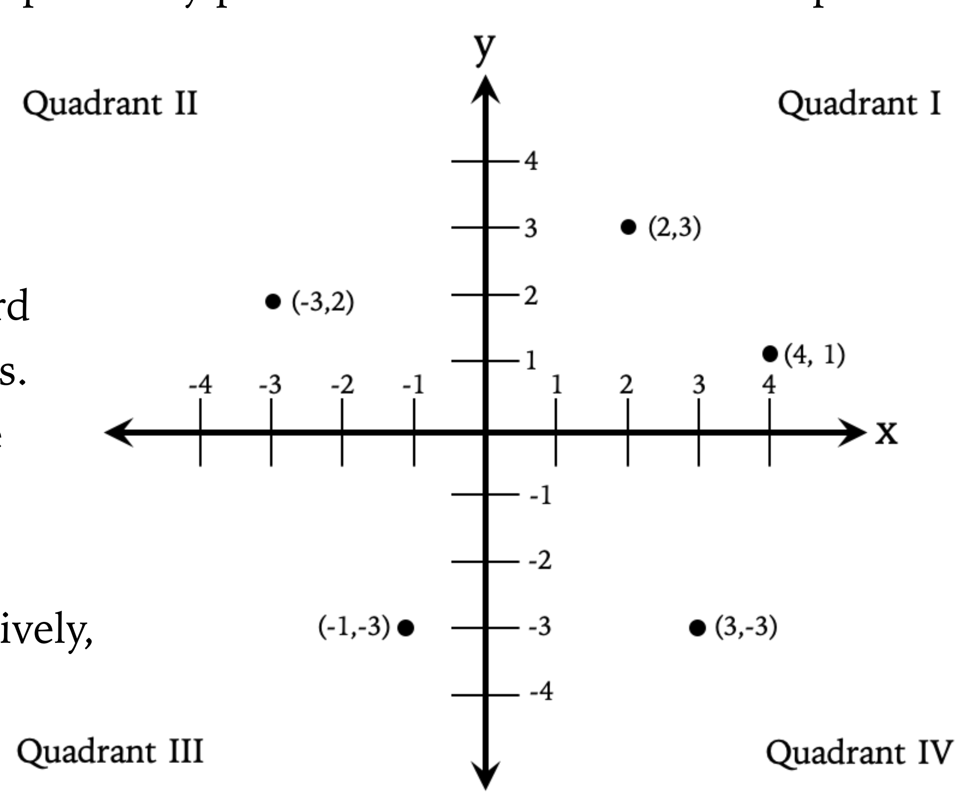
BASIC GRAPHING TECHNIQUES

We will be covering a few basic and important graphing skills that are useful for any field ecologist or Manitoba Envirothon student. Understanding how to make graphs and interpret graphs are a useful skills that are used in many different scientific fields, as well as business, social sciences, and other career paths!

What is a graph? Why are they so important?

Graphs play an important role in understanding of complex natural systems. Graphs are visual representations of numerical systems and equations. When used correctly, graphs can consolidate large amounts of data to help identify patterns and relationships for an audience. Scientific graphs help you to communicate the key messages or findings of your investigation

We will start off with the *Cartesian* coordinate system. We use this standard axis system that when sketching graphs. On the right is the *Cartesian* coordinate system with a few points plotted. The **horizontal** and **vertical** axes, typically called the ***x-axis*** and the ***y-axis*** respectively, divide the coordinate system up into quadrants.



In each quadrant we use the following signs for x and y:

Quadrant I	$x > 0$ or x positive	$y > 0$ or y positive
Quadrant II	$x < 0$ or x negative	$y > 0$ or y positive
Quadrant III	$x < 0$ or x negative	$y < 0$ or y negative
Quadrant IV	$x > 0$ or x positive	$y < 0$ or y negative

Each *point* in the coordinate system is defined by an ordered pair of the form **(x , y)**. The first number listed is the *x-coordinate* of the point (horizontal position) and the second number listed is the *y-coordinate* of the point (vertical position). The ordered pair for any given point **(x , y)** is called the *point coordinates*. The point where the two axes cross is called the origin and has the coordinates (0,0).

Before you create a graph you should consider three things:

1. **Do you need a graph?** Sometimes results can be more easily summarized in a sentence or a table. For example, if you have a large number of categories with a variety of measurements, a table may be a better way to display the results.

2. **What types of variables do you have?** Understanding the types of variables in your data and the statistical design are important to consider when deciding what type of graph you use. There are two main types of data - categorical and measurement.

    Categorical data: the objects being studied are *grouped* into categories based on some *qualitative* trait and the resulting data is categories.

    Examples include: fur colour (white, brown, red, black, etc.), age class (juvenile, subadult, adult), sex (male, female), type of rock (igneous, sedimentary, or metamorphic), etc.

    Measurement data: the objects being studied are *measured* based on some *quantitative* trait and the resulting data are set of numbers.

    Examples include: mass, age, group size, time, length, and temperature

    Measurement can be classified as either:

    1. Discrete/Count - only certain values are possible (e.g., litter size, number of students late for class, number of squirrels in a group, number of raccoon tracks).
    2. Continuous - any value is possible (e.g., mass, age, duration of grooming, temperature)

3. **What is your message?** Graphs need to communicate a message to your readers or audience. As such, it is important to only include data that will help communicate the message the data is telling you.

Describing plots and graphs

Data can be described qualitatively using specific terminology:

- Often we use words that describe the curve or line made by the data: e.g., *linear, exponential, asymptotic, periodic,* etc.
- The strength of those relationships can also be characterized using words like *strong, moderate* or *weak*
- Sometimes we use words like *increasing* and *decreasing* or *positive* and *negative* to describe the relationship of a set of data

In addition to using qualitative terms, we can describe a plot using mathematical expressions. The most common is the equation for a line:

$$y = mx + b$$

where m = slope and b = the y-intercept

Major Parts of a Graph

A graph contains six major parts:

Figure Title – this depicts what the graph is about. The figure title alone should allow readers to understand what the graph is about and where the data came from. Generally, it is located underneath the graph.

Axis titles - each axis should be labeled with which variable it represents and the units it was measured in

Independent variable – this is the variable that is changed or controlled in a scientific experiment. The variable is placed on the *x-axis*.

Dependent variable – this is the variable that is directly affected by the independent variable. It is generally what is being studied or measured. The dependent variable is placed on the *y-axis*.

Scales for each variable – this is required in order to know where to plot the points representing the data. The scale frequently start with 0 and increase in intervals, for example, in multiples of 2, 5, 10, 20 etc. The scale of numbers will be dependent on the data values.

Legend – this is a short descriptive narrative about the graph's data. For example, if you are plotting more than one group of data, it will indicate which colour/symbol/line type represents each group.

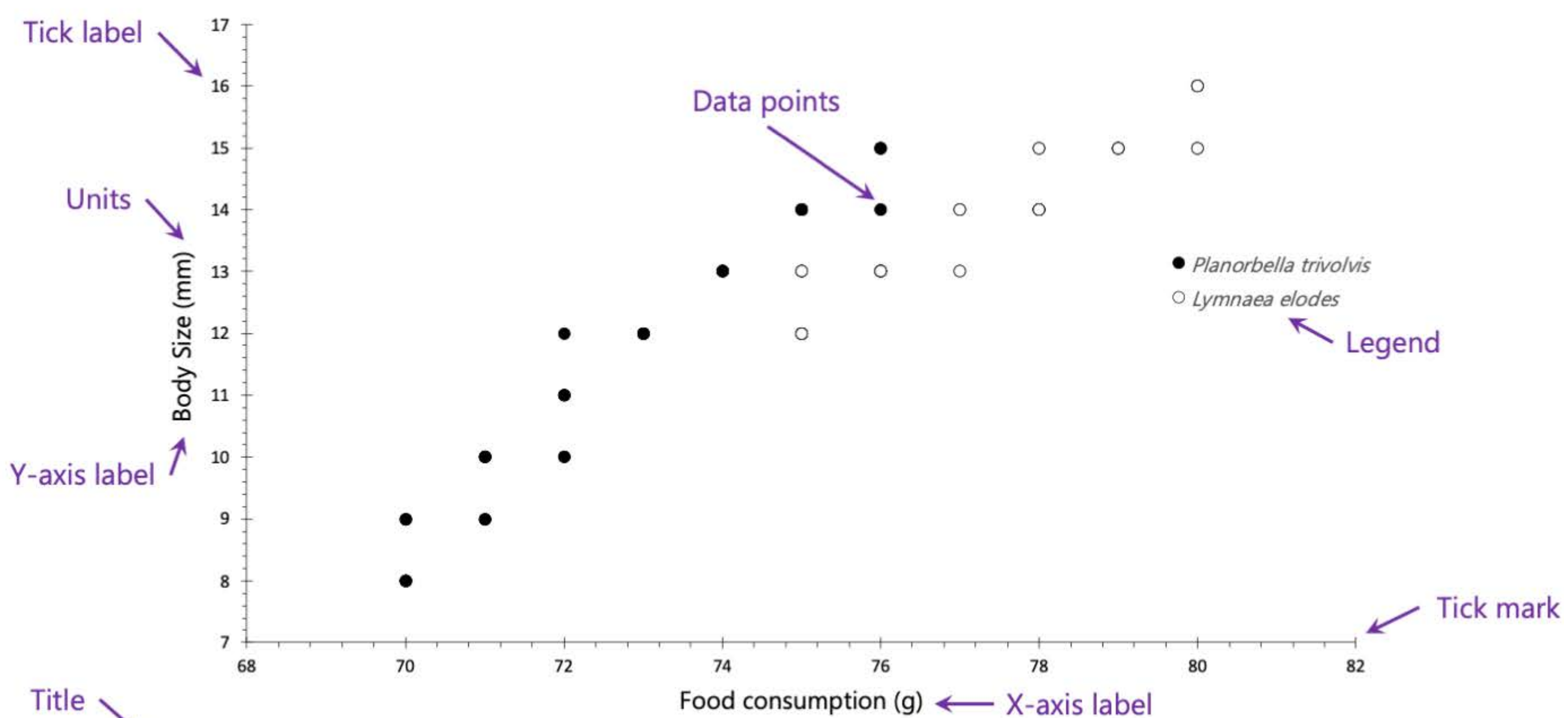


Figure 1. Relationship between food consumption and body size in two species of snails (*Planorbella trivolvis* and *Lymnaea elodes*)

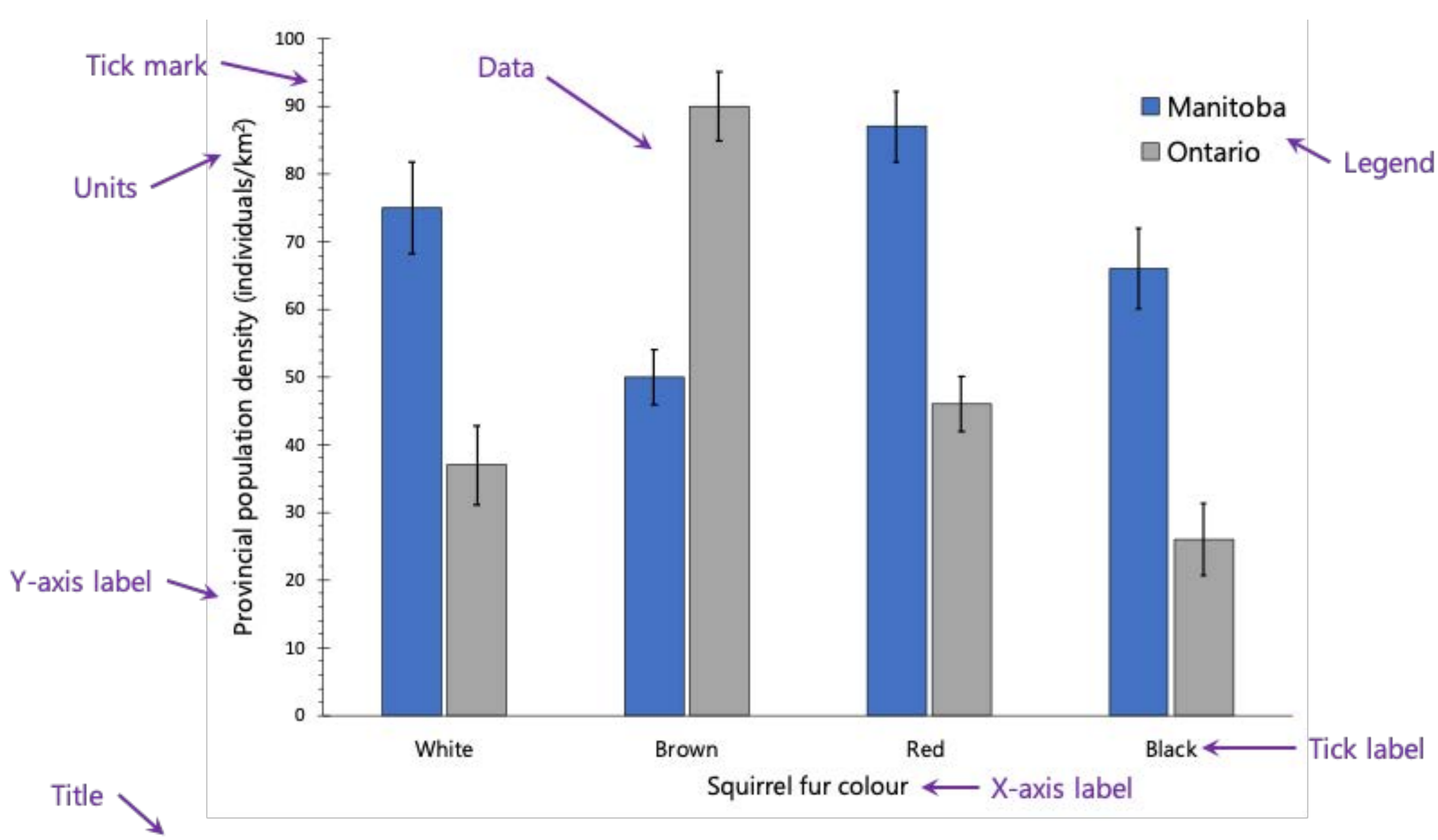
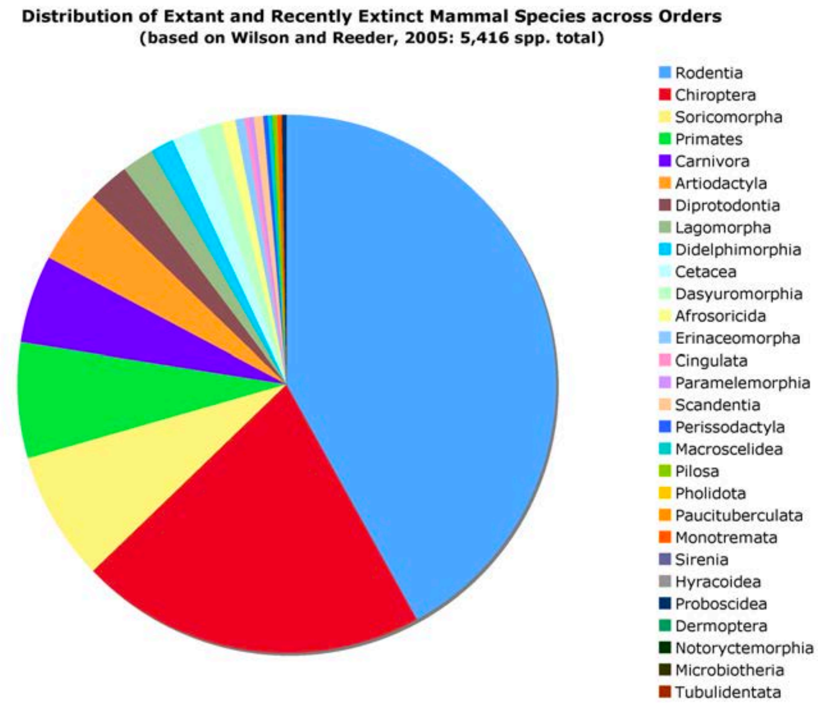


Figure 1. Population density (individuals/km^2) of each squirrel fur colour in Manitoba and Ontario

Pie Graphs

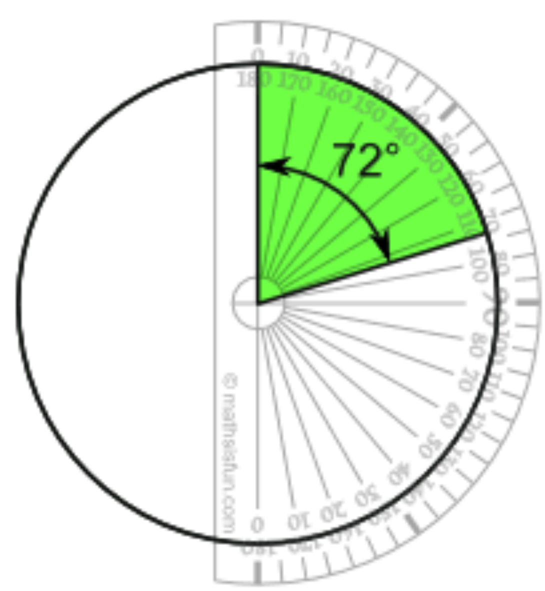


Pie graphs can be used to show percentage or proportional data. A pie chart is a circular graph that shows the relative contribution that different categories contribute to an overall total. Although pie graphs are not generally used in scientific publications, they can often be used in presentations, teaching, business, and other forms of communication to replace tables. They are often used to describe animal or plant community composition, sales analysis, water use distribution, demographics, etc.

How to draw a pie graph:

1. Write each data point down and then list these numbers from high to low. Make sure to give each number their own row to make a column of data points.

2. Make sure to label each column so you do not forget what each numbers mean



3. Add all the numbers together to get your *denominator*

4. Divide each individual number (column) with the *denominator* to obtain the proportion (the proportion of each category out of the total of 1)

5. Multiply each proportion by 360° to calculate the necessary angle for each slice. If you add up all your categories they should equal 360.

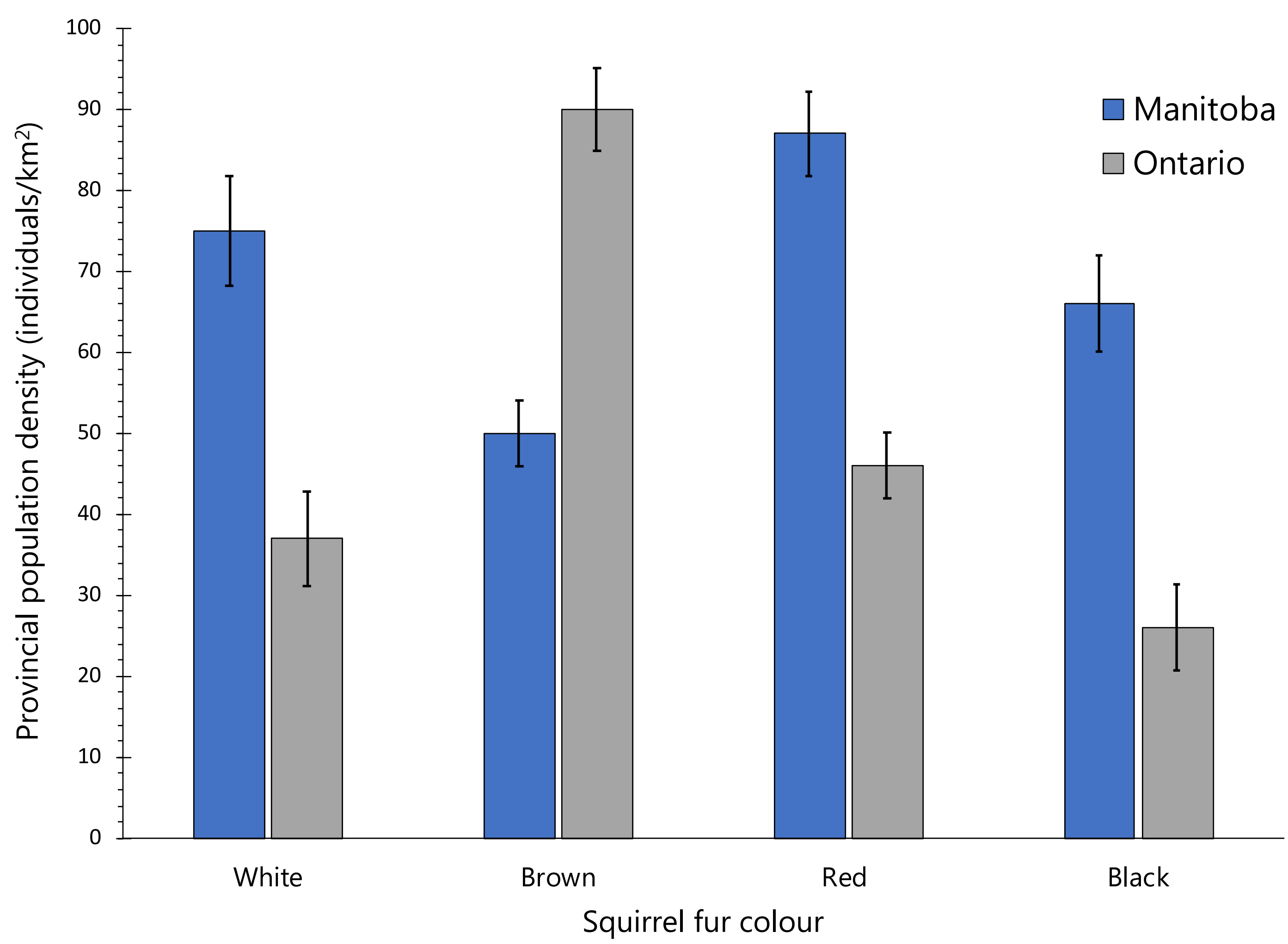
6. Draw a perfect circle (using a mathematical compass), and draw a straight line from the centre to the edge to make the radius. Using a protractor that is lined up with the radius, mark each of your sections, moving the crosshair each time you draw a line (e.g., Your first category is 90°. Mark this location. Your second category is 144. Add 144 to 90 to get 234. Make a hash mark at 234°, etc.).

7. Colour each section and create a legend to match, so each category is clear.

Bar Graphs

A bar graph is used to compare data among different categories. A bar graph may run horizontally or vertically, although vertical is more common. It is important to remember that the longer the bar, the greater the value.

A bar graph will have two axes. On a vertical bar graph, like below, the x-axis shows the data categories (*independent variable*). The y-axis will show the scale (or continuous *dependent variable*). In the example below, squirrel fur colour is the independent variable (risk of being eaten by a predator) and population density is the dependent variable (resulting density in an area).



How to draw a bar graph:

1. **Draw an x and y-axis.** It will look like a large "L" shape.

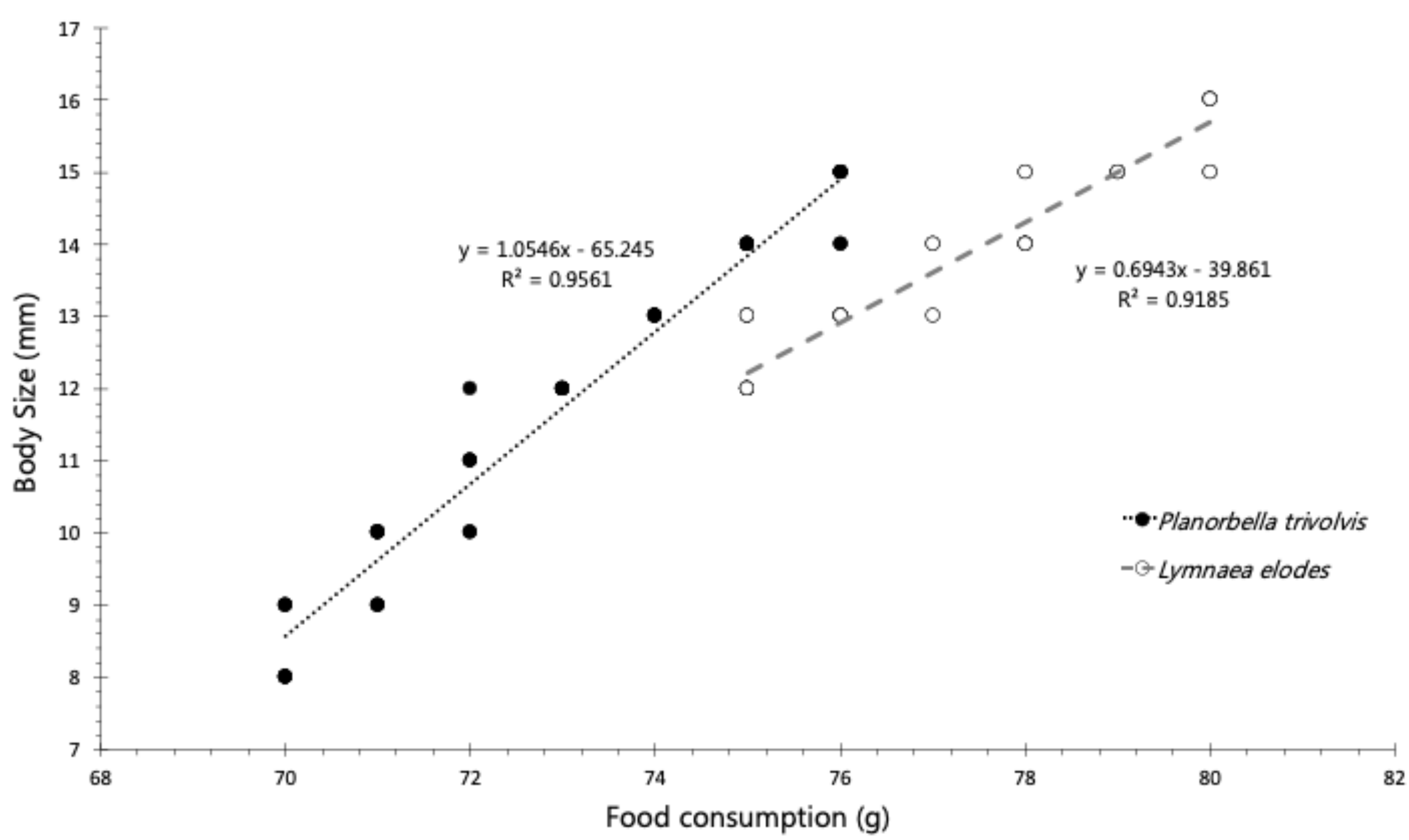
2. **Label the x and y-axis.** Divide the number of squares (convenient units) across the page by the number of categories to find the width of each bar. Divide the y-axis by the highest value of all the bars by the number of squares left above the bottom axis to find what each square represents. If this is a fraction, round up to the nearest whole number.

Label the origin as 0. Each square above 0 increases by the calculated amount until the value is equal to or greater than the largest vertical bar.

3. **Draw your bars:** Extend the base you have marked on the bottom axis to the horizontal line labelled with the value of that bar.

Scatter Plots

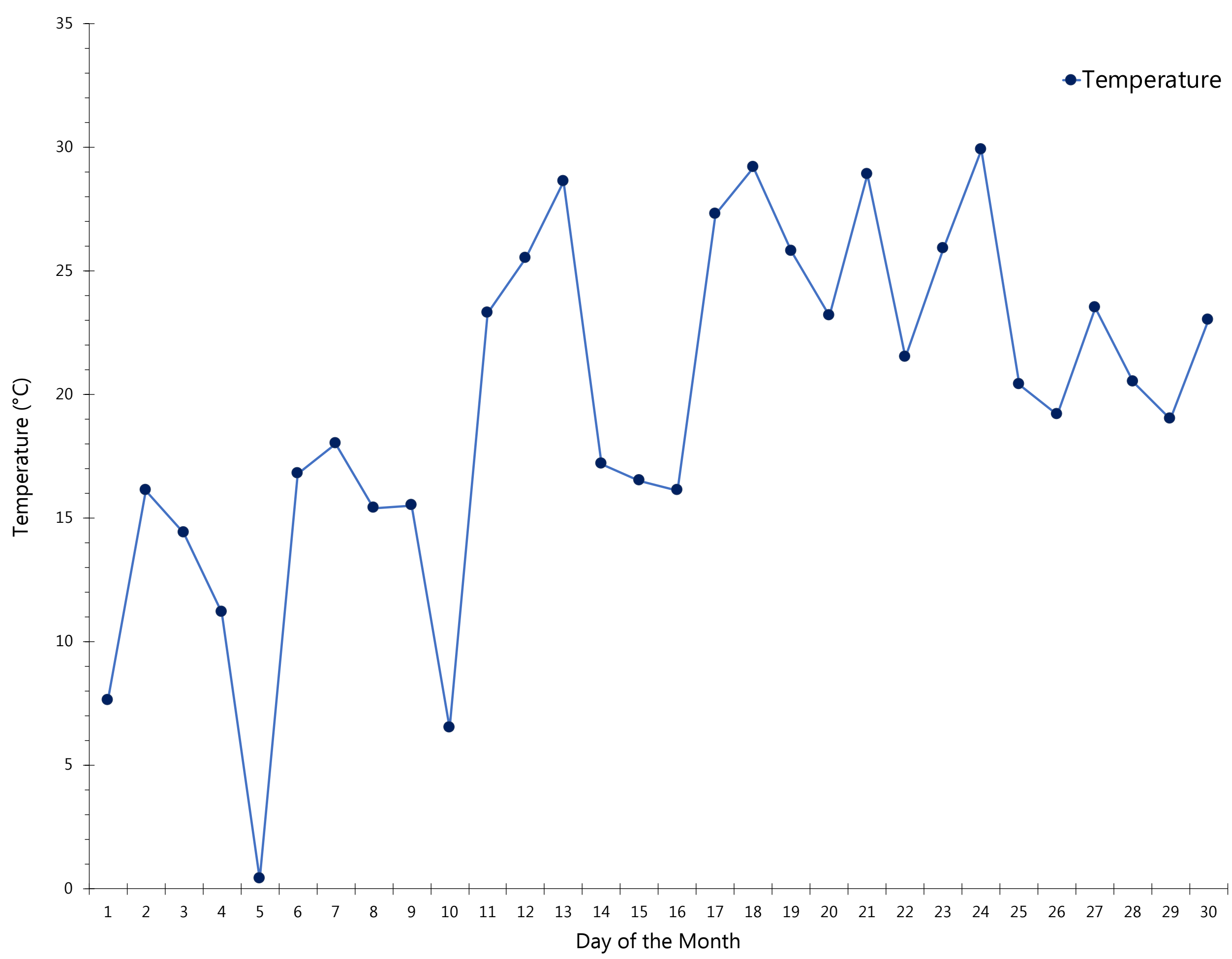
Scatter plots are some of the most common types of graphs used in sciences, like ecology. These plots are similar to line graphs as they start with placing quantitative data points on a standard axis system. The difference between scatter plots and line graphs is that with a scatter plot, individual points are not be connected directly together with a line but, instead a regression line is used to express a trend. This trend can be seen directly through the distribution of points or with the addition of a regression line. A statistical tool is used to mathematically define a regression line and calculate an R-squared (R^2) value. The R-squared value is a statistical measure that represents the proportion of the variance for a *dependent variable* that's explained by an *independent variable* model. The regression line can be linear (appears straight, see below), but it can also take different shapes, like exponential, logarithmic, polynomial, or power.



Drawing a scatter plot is similar to drawing a line graph (described below), except you do not join the points. Although it is possible to calculate the equation of the regression line and draw the line by hand, it is generally now calculated on a computer using programs like Excel, R, SAS, or JMP.

Line Graphs

Line graphs are similar to scatter plots in that they have individual data values as points on a graph. The difference between the two is that in a line graph a line is drawn connecting each data point together. By doing this, the local change from point to point can be seen. Graph creators may do this when it is important to look at the local change between any to pairs of points. Just like a scatter plot, an overall trend can still be seen, but this trend is joined by the local trend between individual or small groups of points. Unlike scatter plots, the *independent variable* can be either measurement or categorical data that has order (e.g., age class, degree of parasitism, months of the year). In the example below, month could be considered measurement or ordinal.



How to draw a line graph:

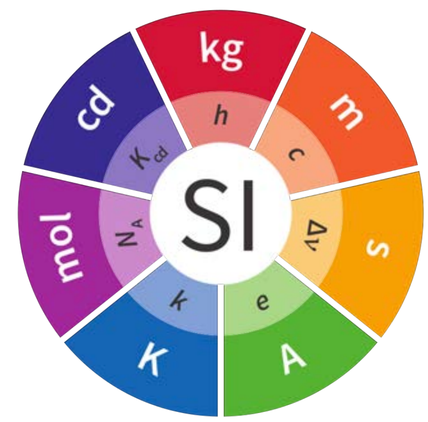
1. Draw the x-axis and y-axis on the graph paper.

2. Label both the axes as per their respective factors. The x-axis represents your *independent variable* and your y-axis represents your *dependent variable*. Both variables should be *measurement* data.

3. Using your data, plot the exact values on the graph. Once you join the points, you can make a clear inference about the trend.

INTERNATIONAL SYSTEM OF UNITS: METRIC SYSTEM

Science uses the **International System of Units** (SI) metric system as a standardized measurement system. It comprises a coherent system of units of measurement starting with seven base units, seconds (unit of time), metre (length), kilogram (mass), ampere (electric current), kelvin (thermodynamic temperature), mole (amount of a substance), and candela (luminous intensity).



The SI system allows for unlimited numbers of additional units, called ‘derived units’, which can be represented as the products of powers of the base units. For example, if we are measuring the area we can use square meter (m^2) as area is calculated by multiplying the length and width of a region, which are both measured in meters. Further, we can state the volume of a cube by using cubic meters (m^3), as it is calculated by multiplying the length, width, and depth of the object, all of which are measured in meters. If we were measuring the speed of an object, we can report it as meter per second, as the speed is the length divided by time.

The SI system also has twenty prefixes to the unit names and unit symbols that may be used when specifying power-of-ten (i.e. decimal) multiples and sub-multiples of SI units. For example, meter is a base unit, but we can measure in kilometres (thousand kilometres (10^3)), centimetres (hundredth of a meter (10^{-2})), millimetres (thousandth of a meter(10^{-3})), micrometers (millionth of a meter(10^{-6})), and nanometers (billionth of a meter (10^{-9})).

Many non-SI units still appear in scientific, technical, and commercial literature. Some of these units have historic and cultural importance and have not yet been replaced by SI alternatives. As such, some of these non-SI units are still considered acceptable. For example, minutes, hours, and days (min, h, d) are very common non-SI units but considered acceptable for scientific publishing. Areas being measured as hectares (10^4 m^2) and volume measured in litres (10^{-3} m^3) are both also acceptable.

All ecologists should be familiar with how to convert between some common non-SI units and SI units (e.g., miles to kilometres, etc.), convert measurements between prefixes (going from cm to m, etc.), and calculate derived units (e.g., calculating area). These skills are not only useful for performing some hands-on skills in the field, but also facilitate better communication between individuals (e.g., travel and cross-cultural communication).

The ability to convert between SI metric and other common measures of length, mass, and temperature is very useful:

Length:

1 kilometre (km) = 0.6 miles	1 mile (mi) = 1.609 kilometres
1 meter (m) = 1.09 yards	1 yard (yd) = 91.44 centimetres
1 centimeter (cm) = 0.39 inches	1 inch (in) = 2.54 centimeters

Temperature conversion:

Convert Celcius to Fahrenheit:	(__°C × 9/5) + 32 = 32°F
Convert Fahrenheit to Celsius:	(__°F − 32) × 5/9 = 0°C

Example:

Convert 68 degrees Fahrenheit to degrees Celsius:

(68°F - 32) × 5/9 = 20 °C

Mass:

1 gram (g) = 0.0353 ounces	1 ounce (oz) = 28.35 g
1 kilogram (kg) = 2.205 pounds	1 pound (lb) = 0.454 kg

DETERMINING LOCATION

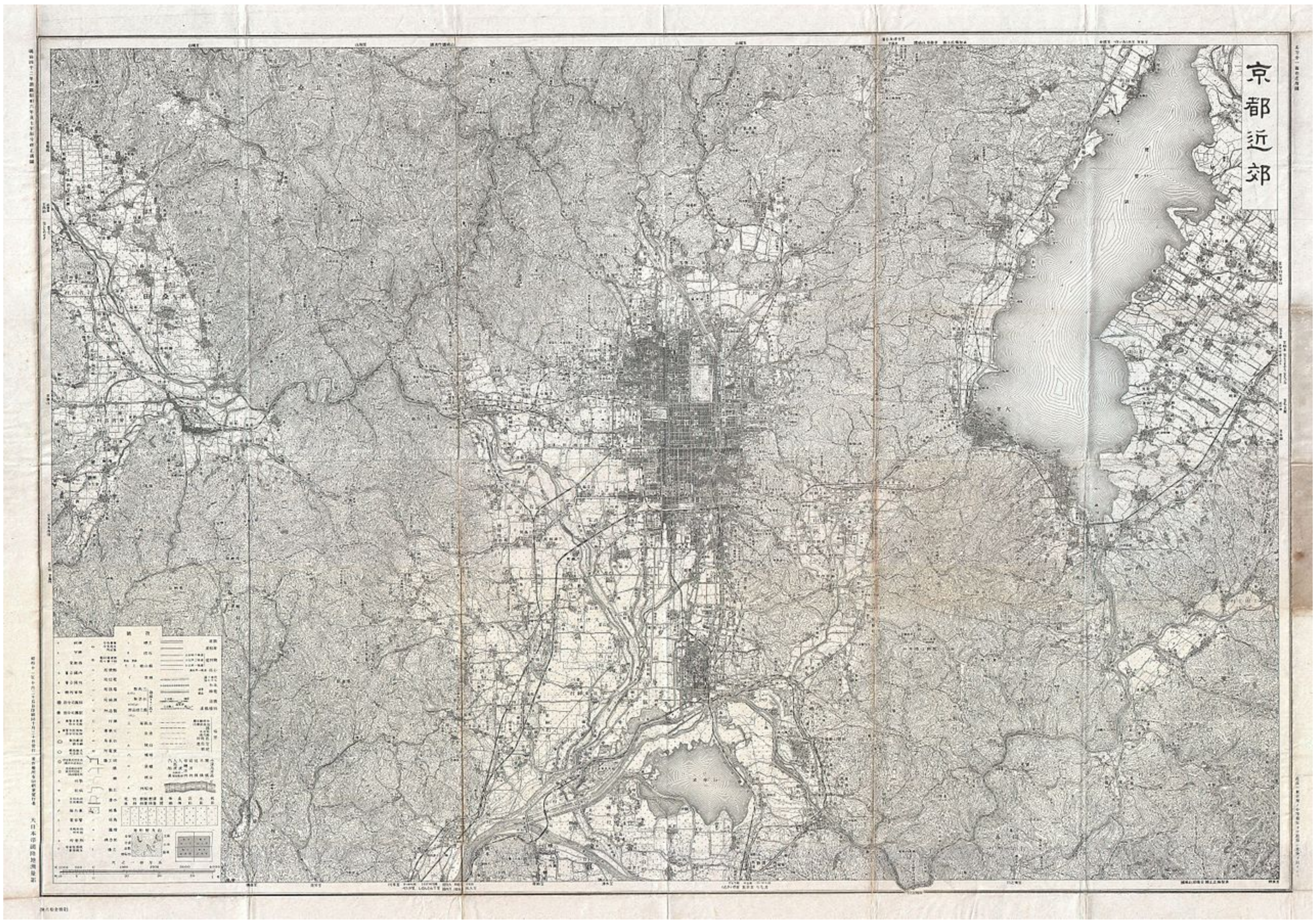
MAPS

Being able to use a map to navigate is an essential skill of anyone who spends time out in wilderness areas, is going out to do scientific field work, or generally is an outdoor enthusiast!

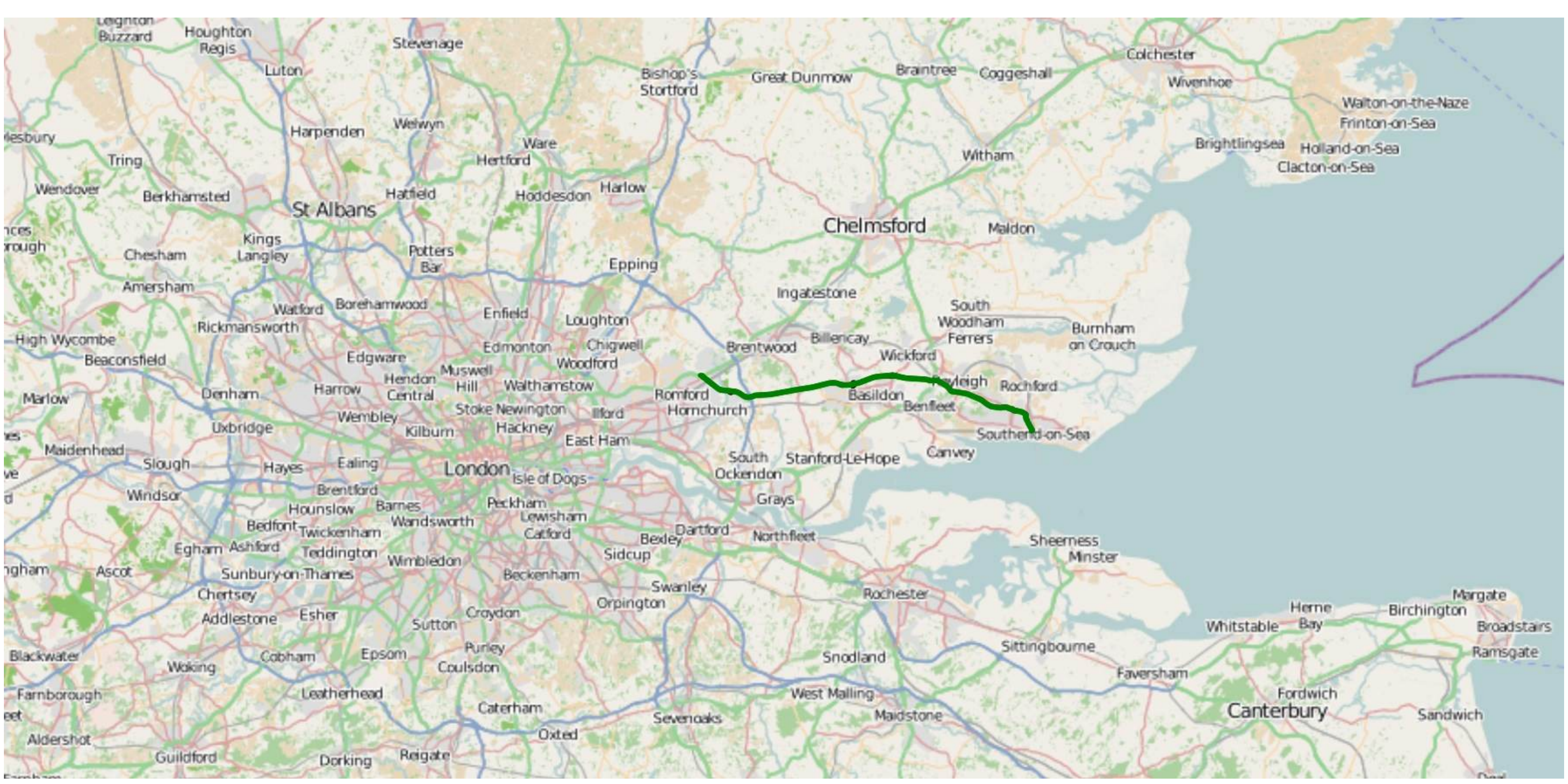
Use the correct type of map

As there are many different types of maps, you want to be sure that you have the right one for your purpose. A tourist sightseeing map will be useless if you're in the remote parts of the Canadian Shield or the Arctic. Below is a quick list of the types of maps and the situations that they're useful for:

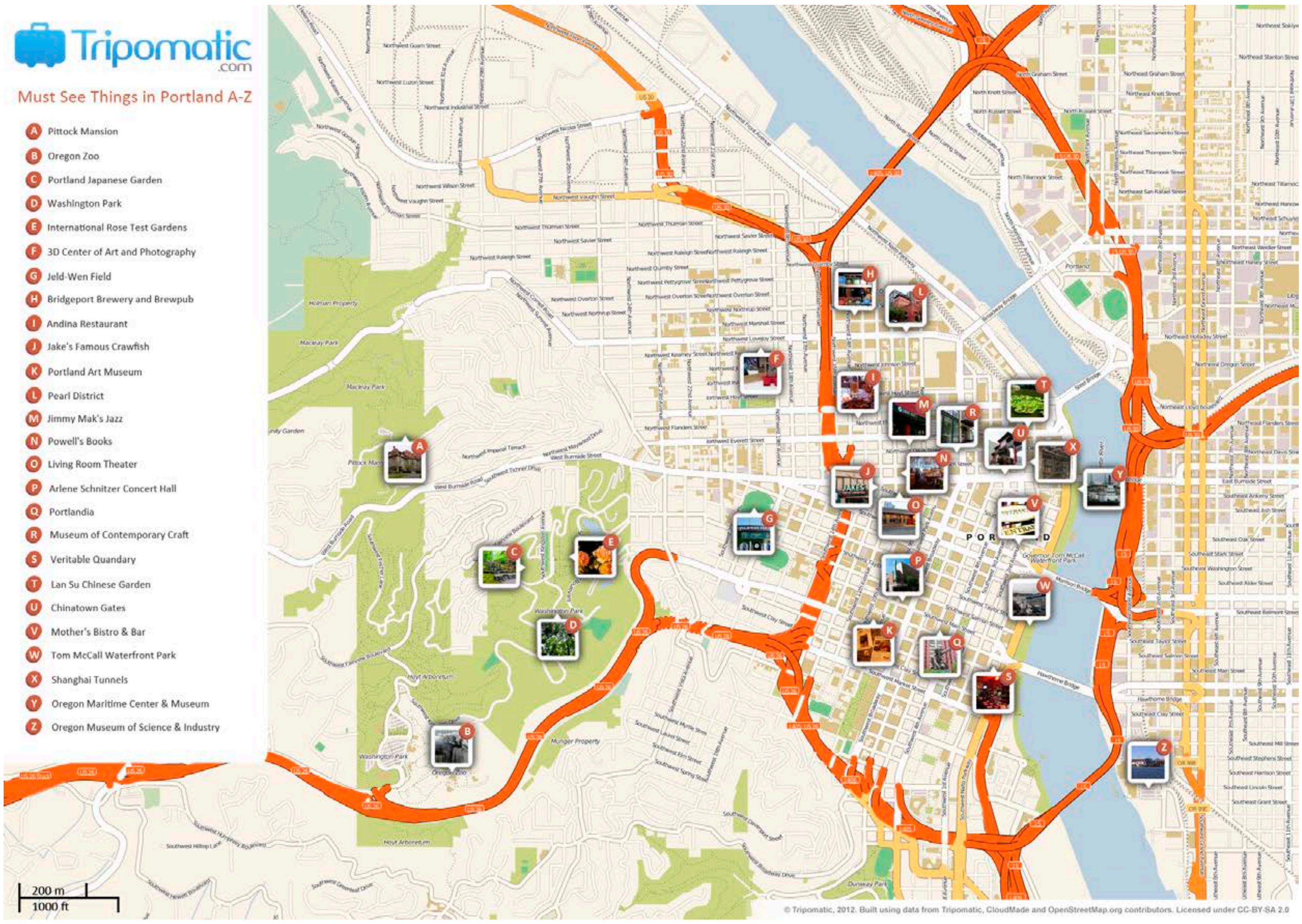
A. **Topographic Map** - a topographic map shows detailed information about the terrain, roads, points of interest, and distances. It is essential for working in wilderness areas.



B. **Road Map** - Road maps show major roads and landmarks in an area. They will not show elevation changes but they are very useful if you are travelling through urban areas.



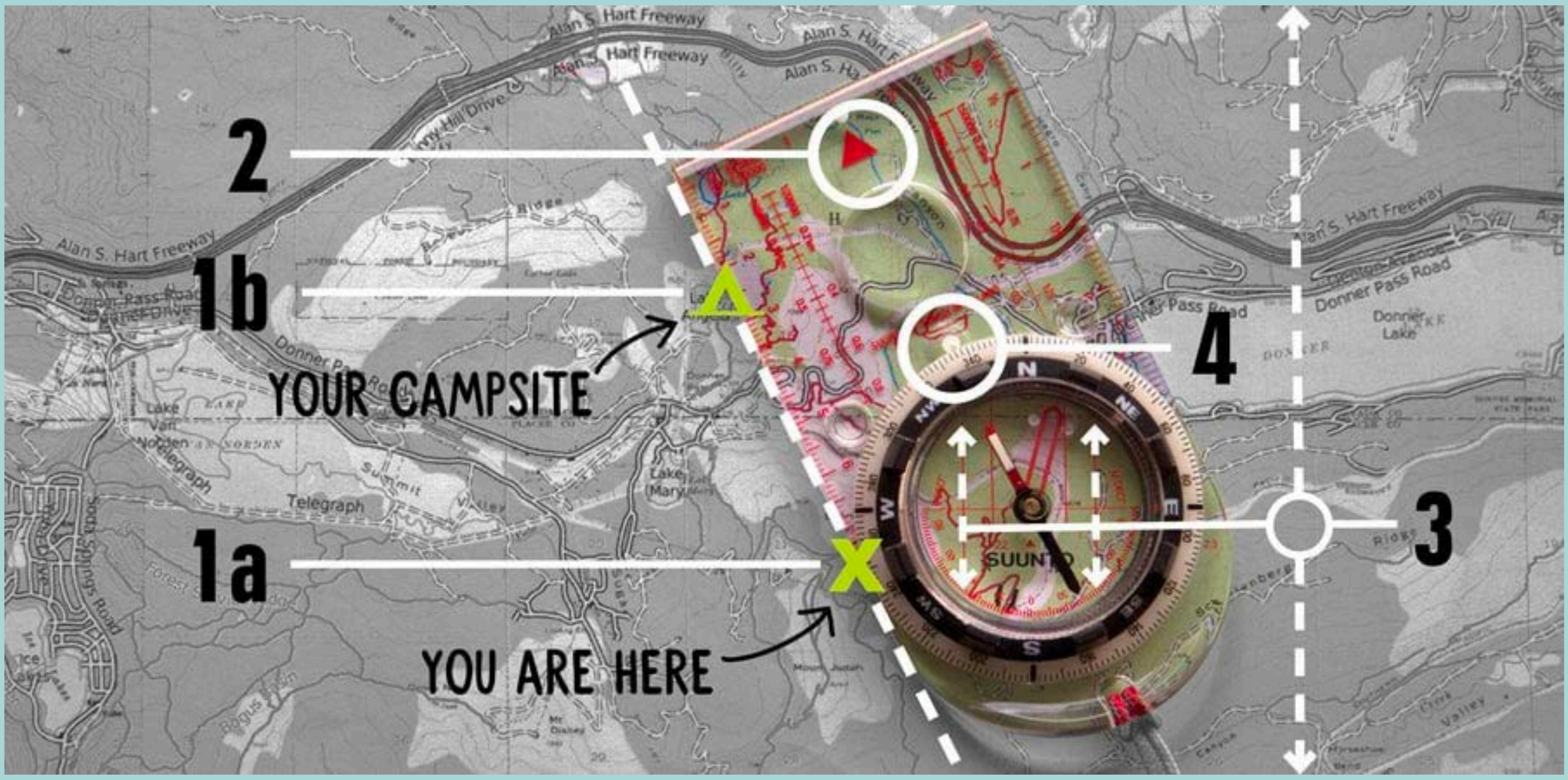
C. **Tourist Map** - a tourist map includes basic roads and highlights landmarks, attractions restaurants, hotels, and other points of interest for people travelling in a new area.



Taking a Bearing from a Map

From ***How to Use a Compass****, REI Co-op Expert Advice, © 2020 Recreational Equipment, Inc.*

https://www.rei.com/learn/expert-advice/navigation-basics.html



You can use a *bearing* to *get to a location* any time *you know where you are* on a map:

1. Set your compass on the map so that the straight side of the *baseplate* lines up between your current position (1a) and the map location for a destination like a campsite (1b).

2. Make sure the direction of *travel arrow* is pointing in the general direction of that campsite (in other words, it's not upside down).

3. Now rotate the *bezel* until the *orienting lines* on the compass are aligned with the north-south grid lines and/or the left and right edges of your map. (Be sure the north marker on the *bezel* is pointing **north** on the map, not south.)

4. Look at the *index line* to read the bearing you've just captured.

Now you can use the compass to follow that bearing to your destination:

5. Hold the compass with the direction of *travel arrow* pointing away from you.

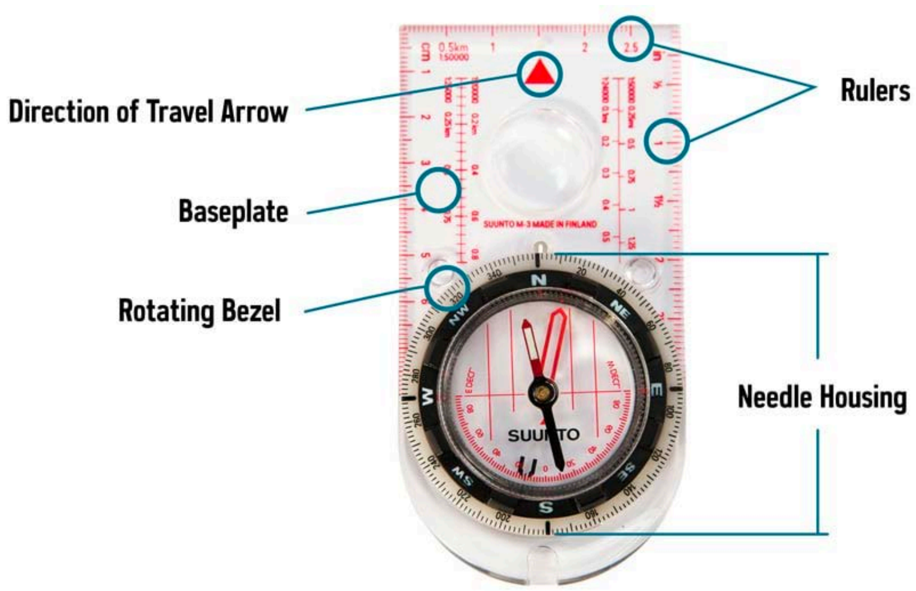
6. Rotate your body until the *magnetized needle* is inside the *orienting arrow*. The direction of travel arrow is now facing the bearing you captured and you can follow it to your destination.

COMPASS

A compass is a tool that can be used with a paper map to navigate in rural or wilderness areas. A simple compass can be an extremely valuable item to have in many situations. It is reliable in all weather conditions, its simplicity makes it extremely reliable, and it can be used without any batteries or electricity. It is important for every user to:

- Identifying the basic parts of a compass
- Understanding and setting declination adjustment
- Using your compass to orient your map
- Understanding bearings and how to use them

Identifying the basic parts of a compass



COMPASS ANATOMY

Baseplate: It can have at least one straight edge for taking bearings and transferring them to your map.

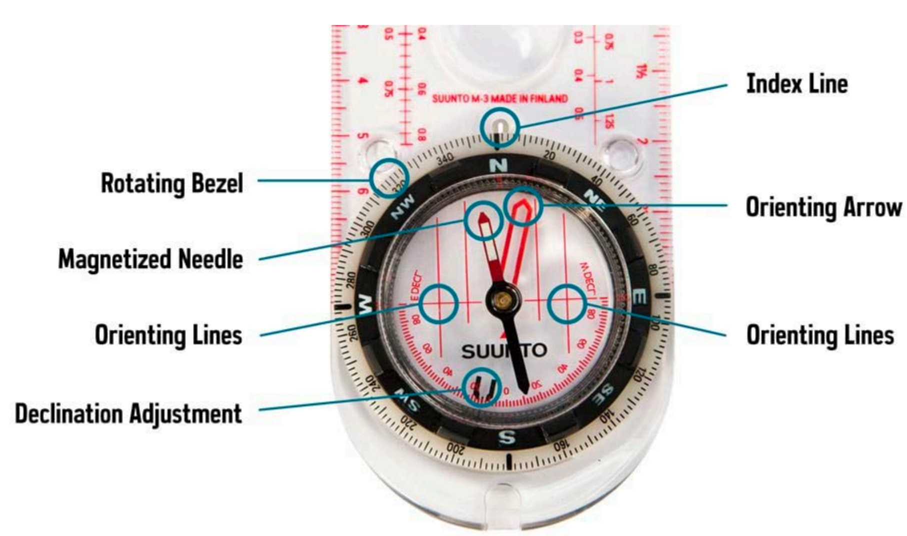
Ruler: Used with your map's scale to determine distances.

Direction-of-travel arrow: Indicates the direction to point the compass when you are taking or following a bearing

Rotating bezel: Outer circle has 360° markings.

Index line: Located directly above the bezel, it's also called a "read bearing here" mark.

Magnetized needle: The end that always points to the magnetic pole is generally coloured red or white.



NEEDLE HOUSING DETAIL

Orienting arrow: The arrow is used to orient the bezel. It has an outline shaped to fit the magnetized end of the needle.

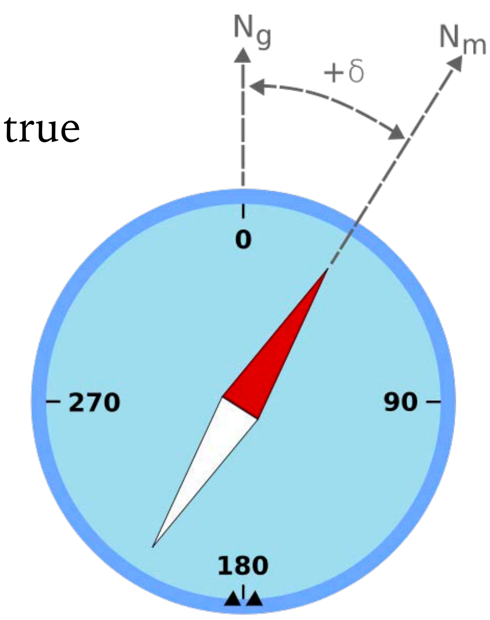
Orienting lines: The parallel lines that rotate with the bezel are the orienting lines. If you correctly align these with the north-south lines on a map, it aligns your orienting arrow with north.

Adjusting Declination

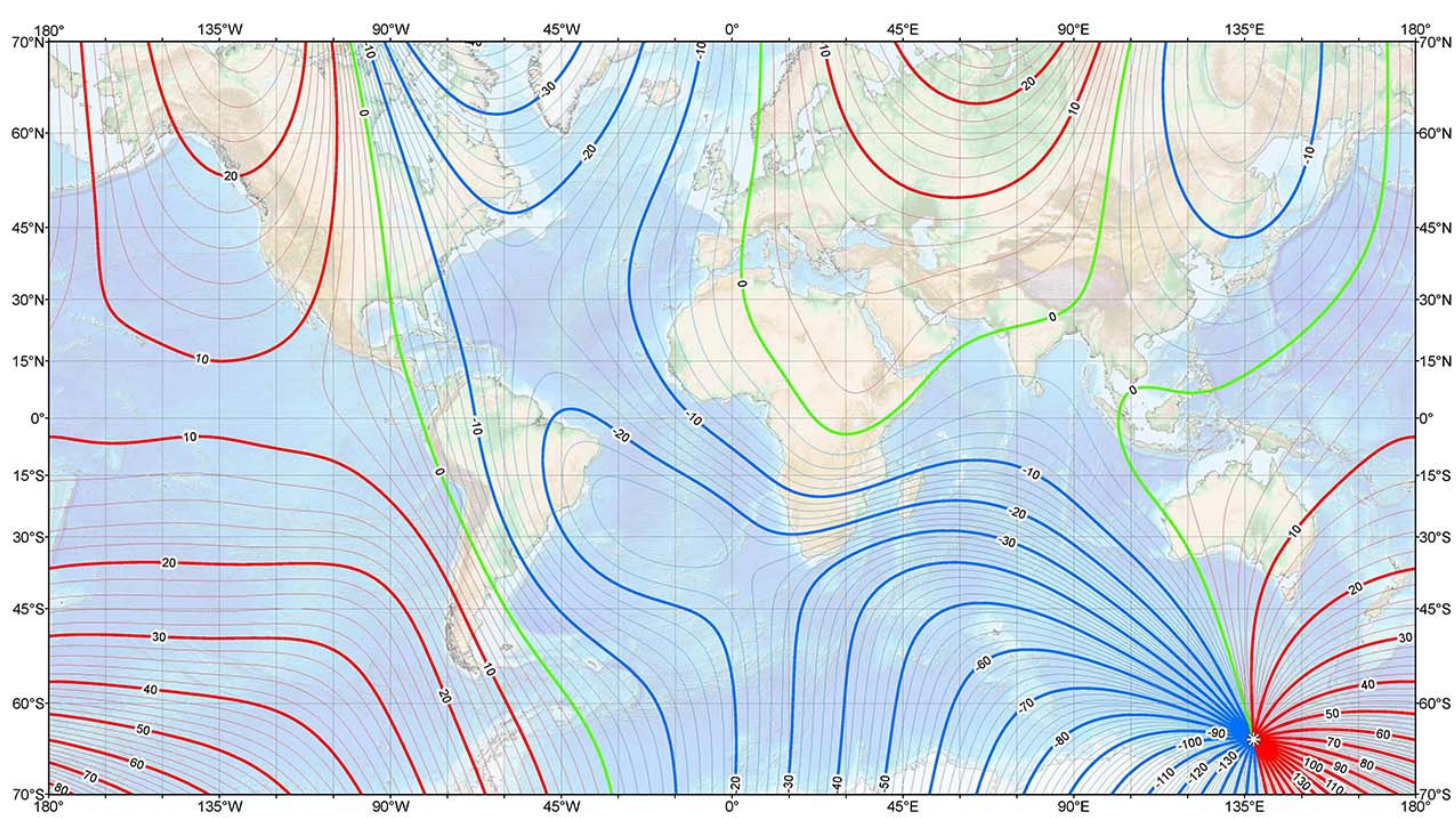
North on a map is at the top and so it is easy to find. In most locations, magnetic north (where your needle points) and true north differ by a few degrees: This difference between north is known as ***declination***.

Generally, declination is positive when magnetic north is east of true north, and negative when it is to the west. Magnetic declination varies both from place to place as well as over time. A single degree of error can set you off course by 30.5 m over 1.6 kilometres, it's important to accurately adjust for declination. Before you can adjust for it, you have to find the declination value in your trip area (see an example of a map below).

The method of adjusting for declination varies with different compass brands and you'll need to follow the provided instructions. Once the declination is set for a trip, you do not have to think about it again until you travel to a faraway place.



Example of magnetic declination showing a compass needle with a "positive" (or "easterly") variation from geographic north. N_g is geographic or true north, N_m is magnetic north, and **δ** is magnetic declination



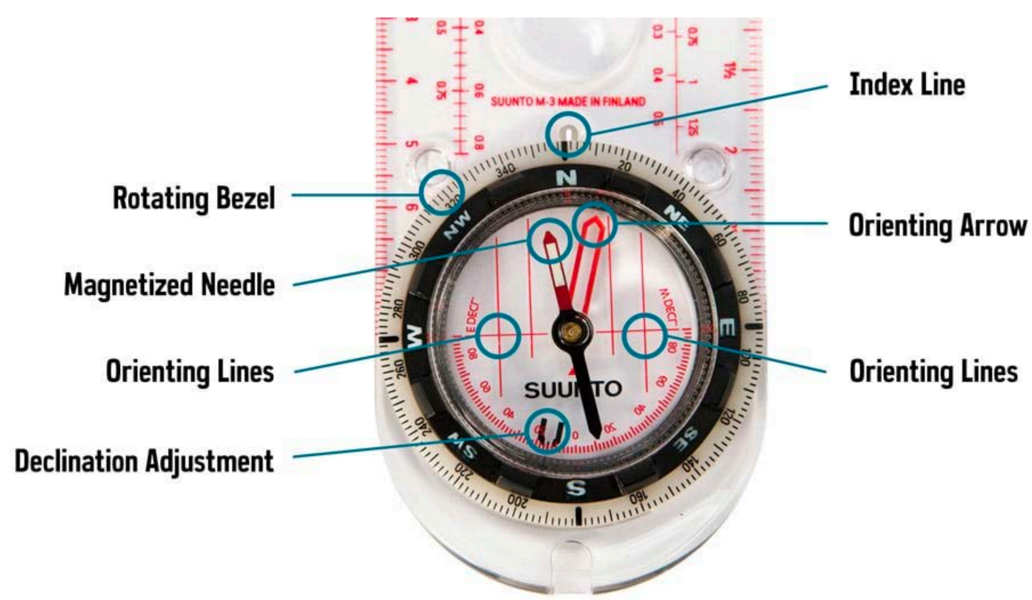
World Magnetic Model - Main Field Declination
© NOAA/NGDC/CIRES

Orient your Map

Map reading is a foundational skill for any ecologist, field researcher, adventurer, or anyone that needs to navigate in the wilderness. You should practice early and often. Before you can do that, though, you have to have your map oriented correctly.

After you set your declination, map orientation is quite simple:

1. Place your compass on the map with the direction of *travel arrow* pointing toward the top of the map.
2. Rotate the *bezel* so that north (N) is lined up with the direction of *travel arrow*.
3. Slide the *baseplate* until one of its straight edges aligns with either the left or right edge of your map. The *travel arrow* direction should still be pointing toward the top of the map.
4. Holding the map and compass, rotate your body until the end of the *magnetic needle* is within the outline of the *orienting arrow*.



NEEDLE HOUSING DETAIL

As the map is now oriented correctly, you can identify nearby landmarks on it. Take time to become familiar with your map and your surroundings before you start moving. Further, keep reading your map along the way.

Taking a Bearing

A bearing is simply a navigationally specific way to describe a direction. For example, instead of heading *northwest* to get to a campsite or another specific location, you might follow a bearing of 315°. **Bearings** are always relative to a specific location. If you follow the same bearing from two different places, you will not end up in the same place.

GLOBAL POSITIONING SYSTEM (GPS)

What is GPS?

The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil and commercial users around the world. It is maintained by the United States government and is freely accessible to anyone with a GPS receiver.

- Advantages include being able to improve map skills and being easily found in case of emergency.
- Disadvantages include people becoming dependant and less self-sufficient as well as requiring batteries.

How does it work?

The UTM System

Because the Earth is a sphere, any representation of its surface on a flat sheet of paper involves distortion.

The Universal Transverse Mercator (UTM) system divides Earth into numbered zones of 6 degrees of longitude. These narrow zones can be mapped with less distortion.

The map below shows the zones that include Canada, Manitoba lies mostly in Zone 14.

- Each zone has a central meridian dividing the zone in half from pole to pole (shown as dashed lines below).
- Each longitude zone is divided into 20 latitude bands of 8 degrees. These bands are lettered starting near the South Pole.
- Southern Manitoba is in latitude band U so our full zone grid reference is 14U.
- We use the Universal Transverse Mercator system as a grid for most of our Topographic Maps and GPS.

ESSENTIAL ITEMS FOR ANY WILDERNESS TRIP

Please note that the information provided here are ***suggestions*** and may not be contain all the information needed to ensure safety. Every individual going on an outdoor adventure needs to do their own research to ensure their personal safety.

Packing efficiently and effectively is essential for ones safety and success on any trip. If you are conducting research on this trip, preparing properly for fieldwork is as important as doing the research in the field. Planning and understanding the conditions you may face are critical.

1. **Narrowing your trip location**: Understanding the key locations of your trip will set you up for success from the get-go.

2. **Route details:** Knowing how many kilometres to go before you sleep, take samples, set up camp, where you will get your water, and other crucial details are important to figure out before you even set foot on the trail.

3. **Gear and supplies:** Do you need permits? What are the expected trail conditions? Will there be problematic animals, plants or insects? How much food will you need? These are the planning questions that will determine how you pack.

PLANNING DESTINATION AND TIMING

If you are planning on a trip that requires active transport (e.g., walking, hiking, biking, etc.), time and distance are important factors to consider.

Time: If you are time limited, you will need to know how many kilometres you and your team or companions want to tackle daily. When choosing your route you want to ensure that it is possible within your time constraints. Knowing your teams physical limitations as well as other factors including elevation gain, how much weight (e.g., backpacks or equipment) people are carrying, and predicted weather conditions are important when deciding how far you or your team will move per day. If you are running experiments or taking samples during the day, the time it takes to do this should also be considered.

Distance: If you are choosing a destination with a fixed length, you will need to divide your total distance by your daily speed to estimate how long it will take to arrive.

Region: It is important to educate yourself on the location you are entering. Who owns this land? Do you ned to obtain permission to travel or work there? What are the natural dangers of the area? Are there specific times of year it is difficult or undesirable to travel to these locations? How accessible are emergency services and the ability to communicate to the outside world?

Group size: If you are travelling by yourself, you may have more flexibility on your hiking speed and where to stop for the night. However, if you are traveling with others you will need to accommodate the pace of the slowest member of your group. Yet there are many benefits of traveling in groups. You can share the weight of equipment (e.g., tent, stoves, etc.). Further, having more people on a trail travelling with you can provide safety in case of injuries or other accidents.

Preparation time: If you are headed out next week, your destination may be different than if your trip is three months away or a year. More time may allow you to plan and prepare better for your trip.

Base camping: It is very common to set up a *base camp,* or an area you return to after spending the day in the *field*. This will allow you to set up a location that you use every day and prevents you from having to set up camp daily as well as carrying all of your equipment daily. This can be very advantageous, especially if you are working on a longer term project.

Time of year and weather: Some trails may be accessible in early spring because they're covered in snow. In other places in the world, rain may cause problems by washing out trials and creating dangerous conditions. Snow storms and blizzards are another factor to consider. It is important to have a better understanding of the weather of your targeted location as certain weather conditions can make travel and work very dangerous.

Consider all scenarios: It is important to consider what your day-today schedule will look like, from same day to multi month trips. Do your research, be objective, and analyze the risk of traveling to different areas and countries to do your work.

GEAR AND SUPPLIES

The equipment you bring on any trip is one of the most important decisions you can make when before embarking. One needs to balance the conditions they will face (e.g., weather, plants, and animals), the length of time they are gone, the weight of carrying the gear, as well as safety when packing and preparing for any adventure.

Permits and passes: Depending on your location, you may need to apply and obtain permits and passes. It is important to bring these with you in order to demonstrate that you have used for permission to be in an area and respect local laws and/or customs. In some areas, travelling without correct documentation can land you in serious legal trouble.

Animals and plants: The most common animals you may need to deal with when travelling are scavengers like raccoons, mice and other rodents. In some areas, you may need to research what to do if you encounter a large predator (e.g., cougar, bears, coyotes) or venomous snakes or insects. The location you are visiting will dictate which of these species you need to prepare for. If you are hiking in bear habitats, you will need to not only know what to do if you encounter one on the trail but also how to store your food to ensure you do not attract more wildlife to your area. The most common plants you may need to deal with are poisonous ivy, oak, and sumac. Many people wear clothing, such as long-sleeved shirts, long pants, socks, and closed shoes in order to keep their skin covered and avoid contact with these plants. Covering your skin may also help reduce your insect bites!

Insects and other problem invertebrates: Find out if biting insects and other invertebrates are a problem where you are going. Insect-repellent clothing, a sleeping net for a hammock, or a head net for meal times can be invaluable for comfort. Some adventurers wear rain gear to prevent mosquito bites.

Packing lists: These items should be part of your field checklist, depending on the length of your trip and your destination

- Hiking boots or shoes (essential for safety) as well as at least one extra pair of socks
- Properly fitted Backpack (size depends on length of trip)
- Tent (for overnight trips)
- Sleeping bag and sleeping pad (for overnight trips)
- Stove and fuel (if you have to cook your own food)
- Kitchen supplies (if you have to cook your own food)
- Plenty of food (absolutely ESSENTIAL, not matter how long your trip)
- Water bottles
- Water-treatment supplies (if you do not have a source of drinkable water)
- Weather-appropriate clothing
    - The clothing you should bring will depend on your location! If you are going to a wet or humid location, make sure you pack clothes that with *dry* quickly like nylon, wool, and polyester. Cotton will not dry as quickly and so it can be dangerous if it keeps moisture against your skin, which may lead serious health

issues. Denim can be especially problematic if it becomes absolutely soaked as it can soak up a large amount of water and become very heavy.
    - Exact packing lists may vary, but there are many online packing lists that have been curated depending on trip length and location (e.g., wtrail.com/packing-list).
- Emergency and hygiene supplies
- Small repair kit for clothing and equipment
- The Ten Essentials (see below)

The Ten Essentials

Packing the *Ten Essentials* whenever you step into the a remote location, even on day hikes, is a very important habit. If something unexpected happens you will truly appreciate the value of carrying these items that could be essential to your survival.

1. *Navigation*: map, compass, altimeter, GPS device, personal locator beacon (PLB) or satellite messenger
2. *Headlamp*: plus extra batteries
3. *Sun protection*: sunglasses, sun-protective clothes and sunscreen
4. *First aid:* including foot care and insect repellent (as needed). One should also make sure to bring any essential medications that they take on a regular basis in case the trip is longer than planned.
5. *Knife*: plus a gear repair kit (please note that there may be restrictions on traveling with knives)
6. *Fire*: matches, lighter, tinder and/or stove
7. *Shelter*: carried at all times (can be a light emergency bivy)
8. *Extra food*: Beyond the minimum you expect to consume
9. *Extra water*: Beyond the minimum you expect to consume
10. *Extra clothes*: Beyond the minimum you expect - bring extra layers or rain gear in case the weather suddenly changes

The exact items you may bring for each of these may vary and should be tailored to the length and location of your trip.

FINAL PREPARATION

Pack your backpack: It is important to pack and try wearing your backpack before you leave. Once you put everything in your pack and hoist it for the first time, you might decide you do not need particular items. It is just as important not to overpack for a trip as that extra weight of equipment you may be carrying can also cause problems (e.g., you spend much more energy moving!).

Check the weather: It is essential to check up to date forecasts for your trip. You will either need to plan accordingly based on what you learn, or if the weather is dangerous, consider postponing or canceling the trip.

Share your itinerary: You should **always** leave your detailed itinerary with someone you trust who is not travelling with you. Write down who to contact and when, if you have not returned at your expected time. If you are hiking from a parked car, leave a piece of paper with contact information under the front seat of your car.

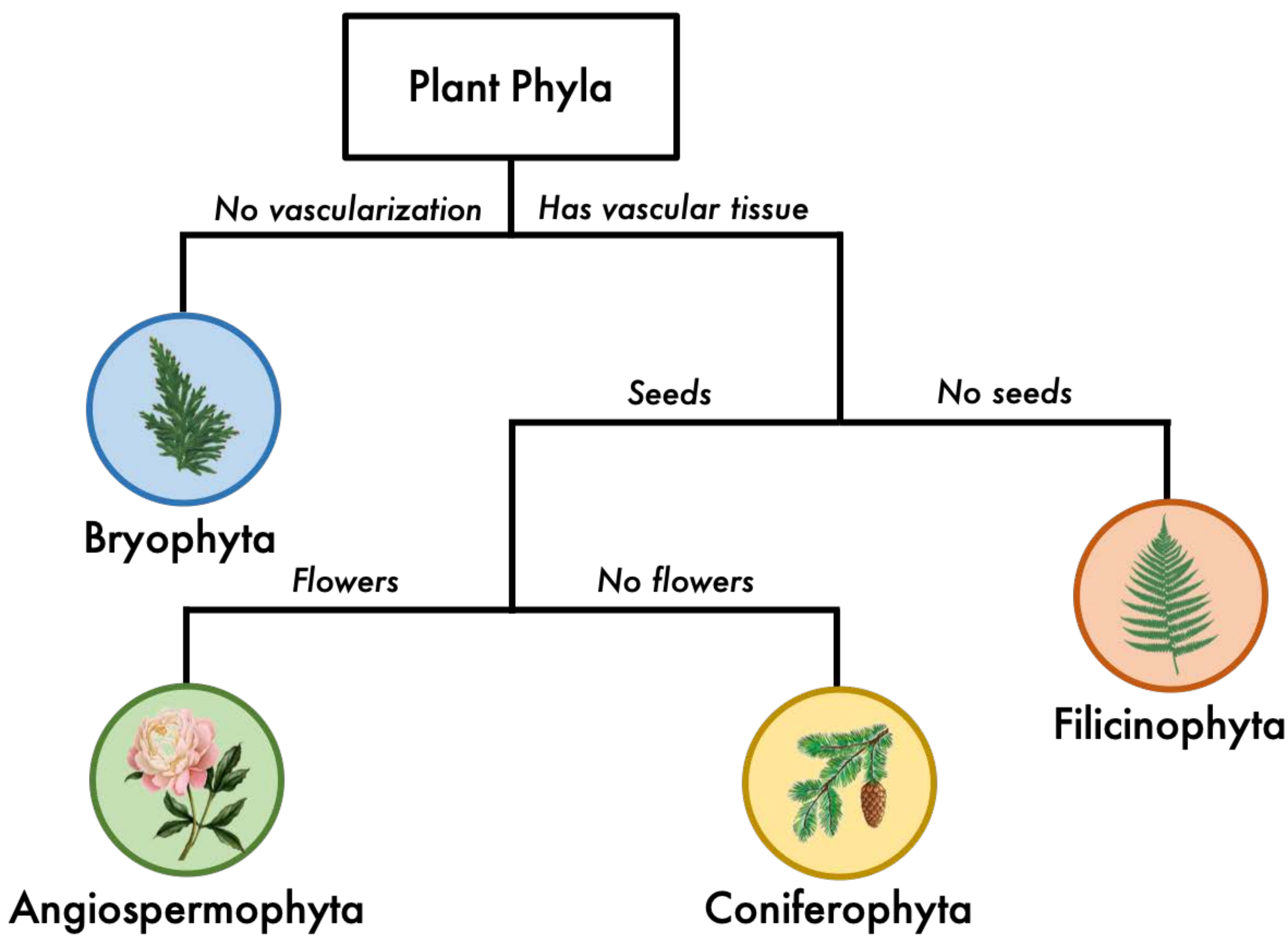
IDENTIFYING SPECIES

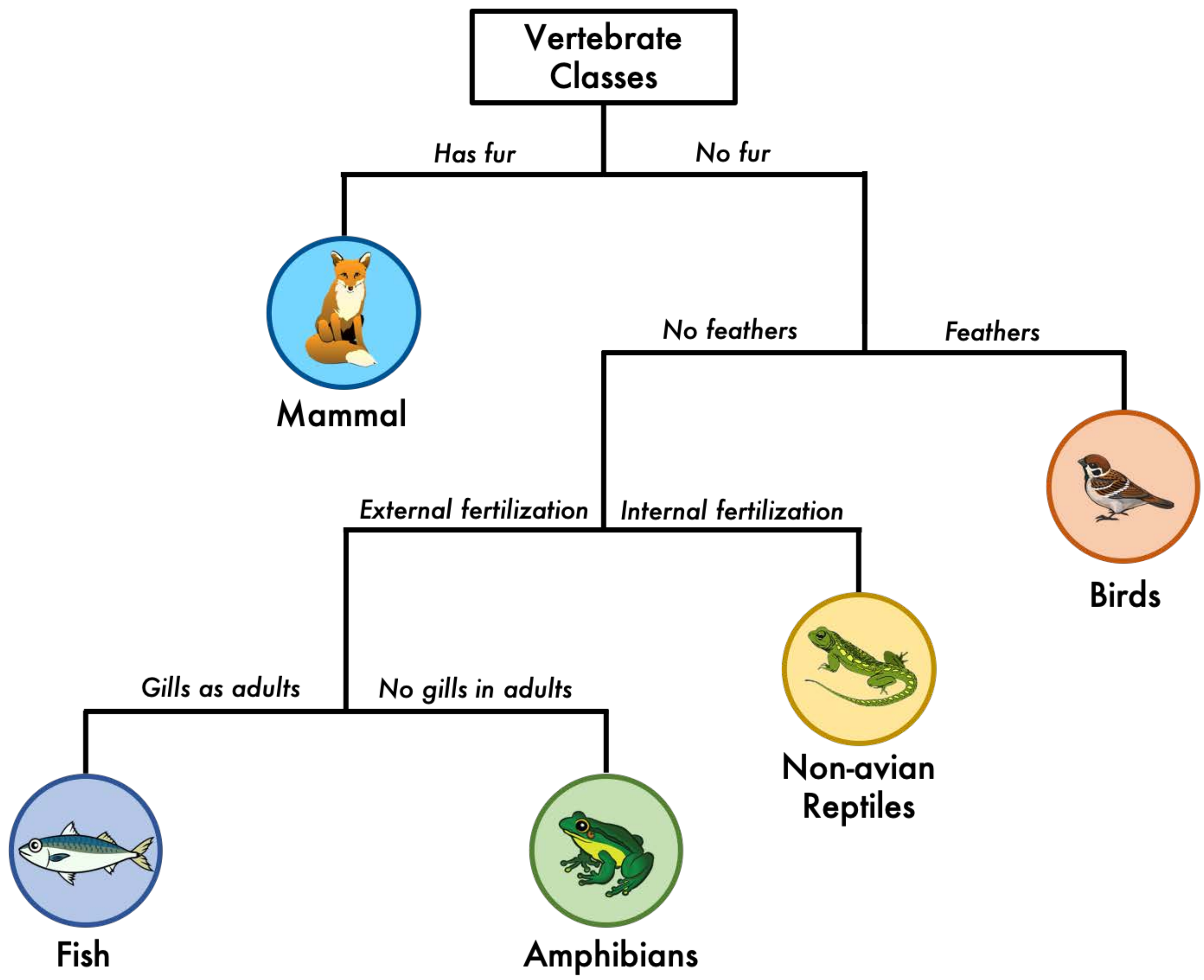
DICHOTOMOUS KEYS

A dichotomous key is a method of identification whereby groups of organisms are divided into two categories repeatedly. With each sequential division, more information is revealed about the specific features of a particular species. When the specimen no longer shares all of the selected characteristics with any organism, it has been identified.

When using a dichotomous key to identify specimens it is preferable to use features that do not change. Size, colouration and behavioural patterns may vary among individuals and across lifetimes. Physical structures (e.g number of limbs) and biological processes (e.g. reproduction methods) make for better characteristics.

Examples of dichotomous keys:





Dichotomous keys are usually represented as a branding flowchart (like above), or a series of paired statements laid out in a numbered sequence (like below).

Key to Invertebrates Phyla

1. Body plan without distinct symmetry, lack organs, aquatic attached to substrate in grey, brownish, or greenish masses……………………………………………….**Phylum Porifera**

   Having distinct symmetry, either radical or bilateral…………………………..…………..2

2. Radially symmetrical (a basic body plan in which the organism can be divided into similar halves by passing a plane at any angle along a central axis), with a central mouth leading to a digestive cavity with no anus. Usually clear and jelly-like, mostly attached to substrate, with stinging cells on tentacles……………………………….**Phylum Cnidaria**

   Bilaterally symmetrical (having identical parts on each side of an axis)……….………….3

3. Soft-bodied, worm-like, with no exoskeleton or cuticle (no hard external surface). Digestive system when present with a single opening. Acoelomate. Free living or parasitic.………………………………………………………….**Phylum Platyhelminthes**

With a complete digestive tract; a tube connecting mouth to anus............................4

4. Legs, tentacles, muscular foot, or segmentation absent 5

With either legs, segments, muscular foot, or shell..6

5. Microscopic aquatic animals with one or two oral rings of cilia for feeding. Body jointed..**Phylum Rotifera**

6. Cylindrical worm-like body of constant shape, tampered at both ends, with a cuticle (tough external surface). Both free-living and parasitic representatives...**Phylum Nematoda**

7. Soft-bodied, with a muscular foot, usually with a calcareous shell (except slugs) and a fleshy mantle covering the internal organs...................................**Phylum Mollusca**

Not with the above characteristics; if a hinged shell is present the animal has jointed legs 7

8. Body segmented...8

Body not segmented. With a calcareous spiny skin. Adults secondarily radially symmetrical. Locomotion via tube feet. Marine ....**Phylum Echinodermata**

9. Body with jointed appendages which may be modified for functions such as feeding, locomotion, defence, mating, and sensory............................**Phylum Arthropoda (9)**

Body not bearing jointed appendages. Segments with or without bristles..**Phylum Annelida**

10. Antennae absent; body consisting of cephalothorax and abdomen; adults usually have *four pairs of legs*...**Subphylum Chelicerata**

Antennae present..**Subphylum Mandibulata (10)**

11. Adults and larvae usually with three pairs of legs, and a single pair of antennae, adults are frequently winged..**Class Insecta**

Two pairs of antennae; adults with variable numbers of legs; never with wings...**Class Crustacea**

Dichotomous keys are widely used and employed in a variety of scientific fields. Often one of the best ways to learn how to use a key is to make one yourself! The following example was created by the National Park Service, United States Government.

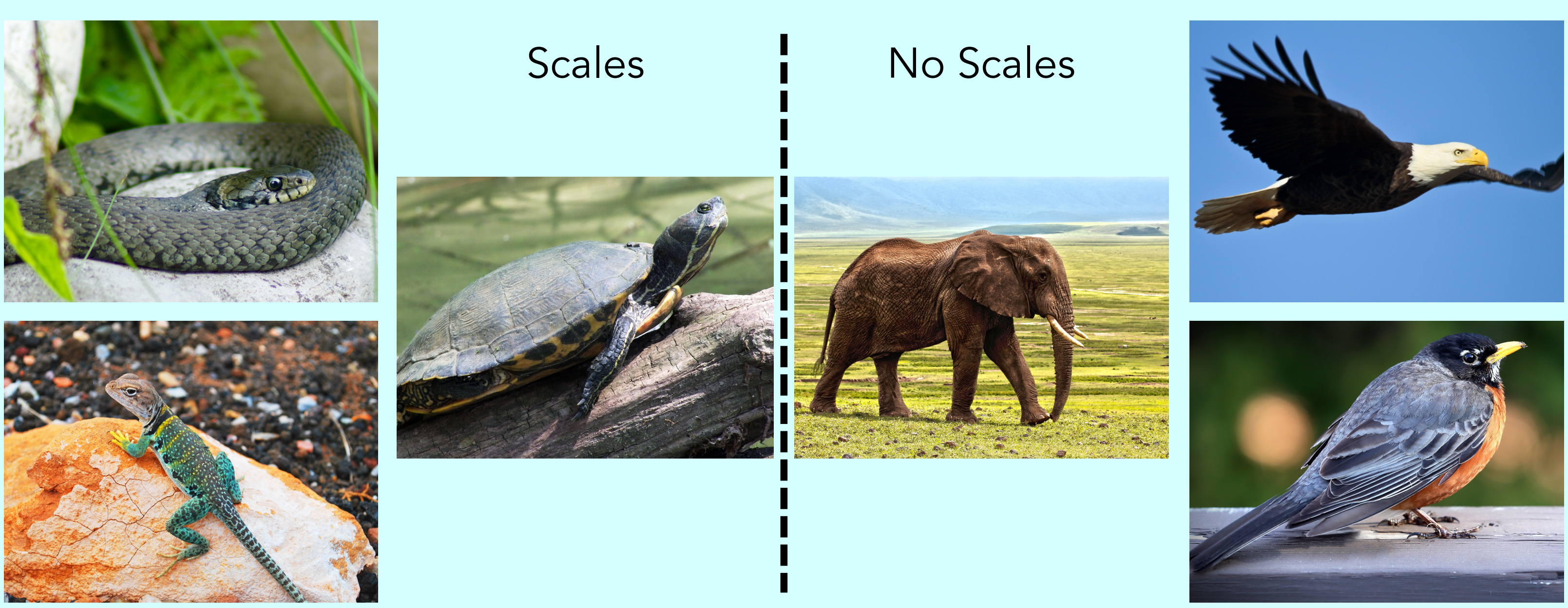
Making a Dichotomous Key

(based on teaching tools developed by National Park Service, USA)

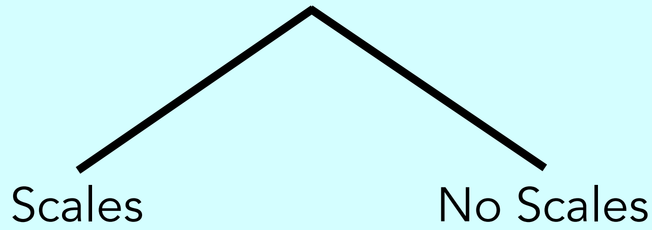
Use the following step-by-step directions to making a dichotomous key!

1. We need to make a key to help others identify the following animals based on physical characteristics.

Let's pick a characteristic that has an opposite: an animal can have *scales or no scales*. It is easier to use than *scales or feathers.* Now we will divide the pictures into two groups based on this characteristic



Now we draw a **branch** for that part of the tree.

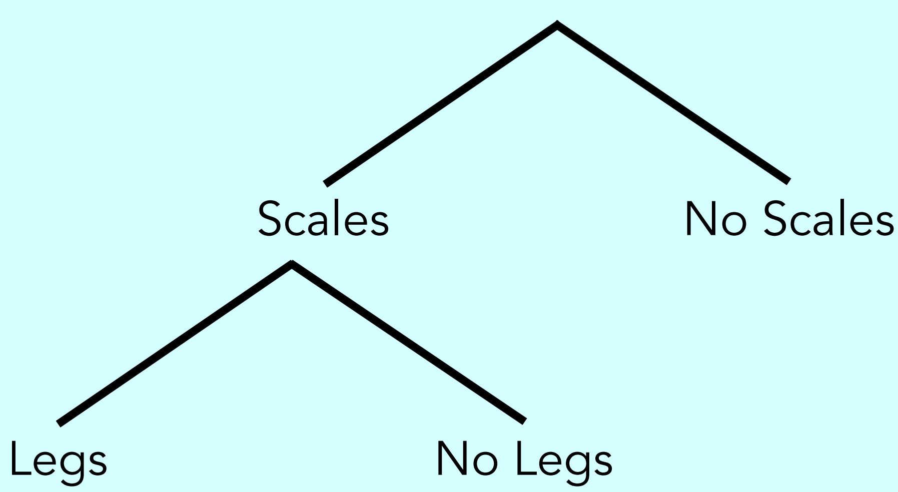


Now, we choose the animals from one of the groups, the scaled animals, and we need to pick another characteristic that divides the animals into two more groups. In this case, we can use *legs or no legs*. Now we physically divide our pictures into two.

Legs

No Legs

Now we draw a **branch** for that part of the tree.



We need to continue down this branching key until only one animal remains per branch. As we do this, we will enter the name of the animal into these branches.

Scales No Scales

Legs No Legs (**Snake**)

Shell (**Turtle**) No Shell (**Lizard**)

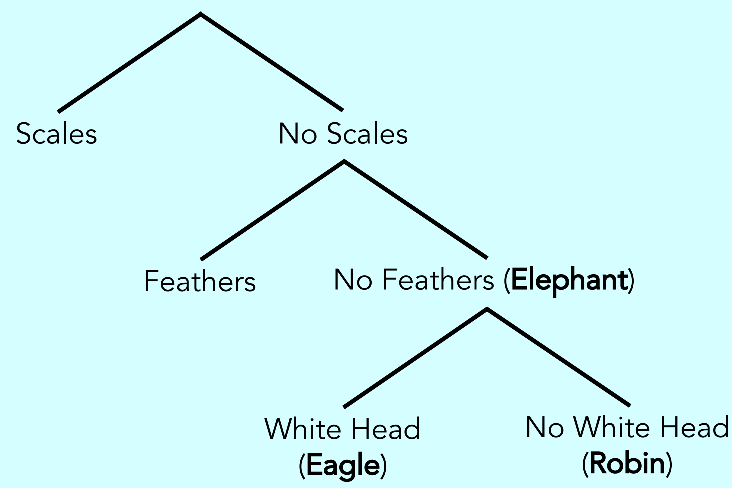
Now we will follow the same procedure for the other side of the **branching key.**

No Feathers Feathers

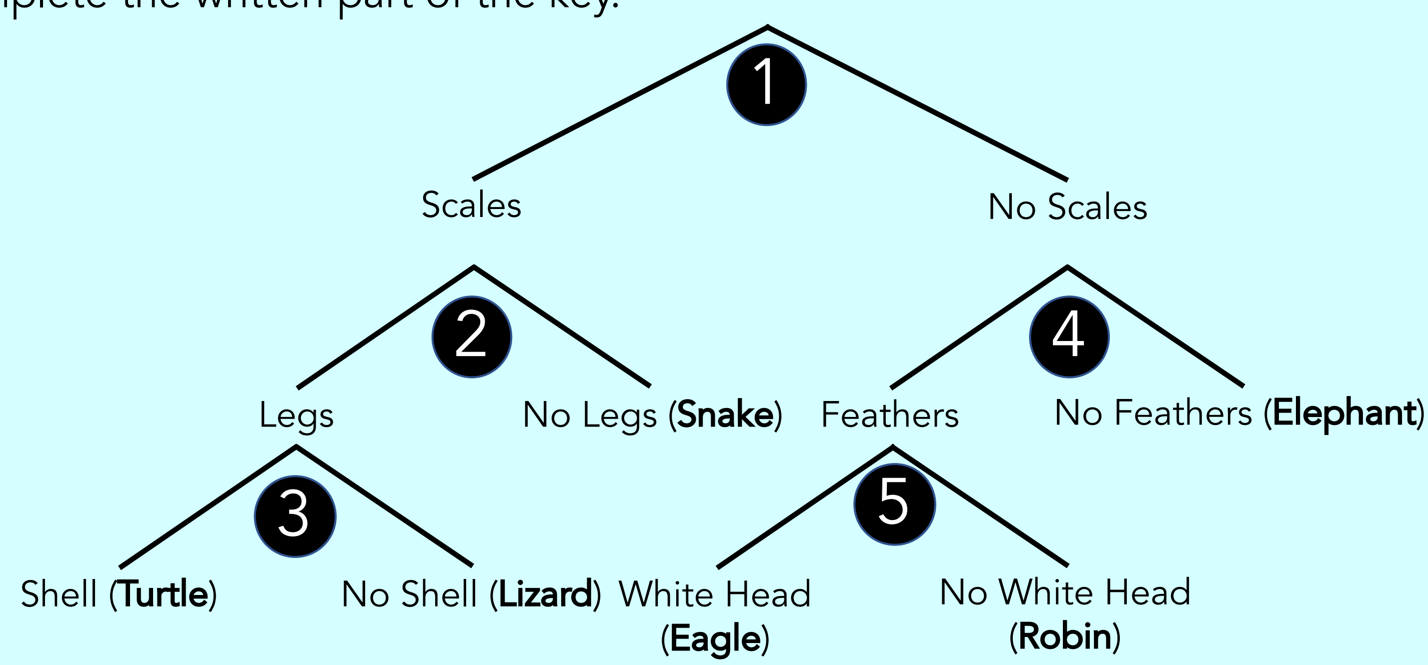
Scales No Scales

Feathers No Feathers

The key will be complete when all animals have been identified.



Finally, we can add numbers to the branching key by putting a number at the juncture of any choice of characteristic, in order to get the information needed to complete the written part of the key.



We can now create a written key by following the numbers put beside each characteristic. The key is complete when all animals have been identified.

1. Scales..go to 2
   No Scales.. go to 4
2. Legs...go to 3
   No Legs... **Snake**
3. Shell...**Turtle**
   No Shell... **Lizard**
4. Feathers... go to 5
   No Feathers...................................... **Elephant**
5. White Head...................................... **Bald Eagle**
   No White Head................................. **Robin**

FIELD NOTES

A wildlife biologist or naturalist should always keep field notes and a journal as an essential record of activities and observations. Keeping accurate field notes and a good journal enables one or others to return to the same areas in the future and look for important ecological changes. A journal also provides a good record of one's investigations, observations, thoughts, speculations, and random musings of the field. Although certain details may not seem useful or applicable at the time, great discoveries and revelations have been made by referencing back to ones field notes.

Good field notes include quite a few things:

1. Name of observer(s)
2. Date, time, and locality of the day's observations
3. Numbered pages
4. Weather should be noted at the beginning of the day and whenever significant changes occur
5. Recent events (fires, storms, or droughts, for example)
6. Brief description of the habitat including the topography (flood plain, forest, sedge meadow, fen, etc.) and vegetation (oak-pine forest, wetland, etc.)
7. GPS location of any observation
8. Route traveled
9. Quantitative (numerical) data (for example estimates of the numbers or sizes of individual plants and animals seen, frequency of events, etc.) and other observations (e.g. other animals or plants)
10. Records of collected items (e.g. samples taken such as plant samples or fecal samples)
11. Photos taken and their location
12. Thoughts, questions, speculations, etc.

An example of a page out of a field journal:

Page 1

Name: J. Doe
Date: 22 04 2013
Time: 19:30

Location: Den E25, Wapusk National Park (near Nestor One)
Habitat: Tundra, beach ridge, fox den
Temperature: -21°C **Humidity:** 60%
GPS Coordinates: 15 473110 6473943 UTM

Data and Observations:

- Fox burrow present with fresh digging, two entrances
- Fox feces present
- Urine present
- White hair (Arctic fox) present in fox burrow
- No fox tracks present
- Ptarmigan present at den with lots of ptarmigan feces
- Large tracks (likely polar bear) present at outer edge of den
- Deep snow but some vegetation still obvious

Photos:
IMG_0986 – burrow opening
IMG_0987 – researching examining burrow opening
IMG_0988 – Ptarmigan

Collected Items:

- Fox feces collected and labeled
- White hair from burrow opening

Field journals can be more detailed depending on the project. In many behavioural observation studies or mark-recapture studies, the researcher often records the mass of the animal, sex, tag number, pit tag, spine length, etc. The more detailed the field notes the easier it is to come back to them as a reference.

USING A FIELD GUIDE

Field guides are resources written to help the reader identify plants, animals, or other non-living things (e.g. minerals and rocks) that occur in nature. Historically, field guides have been books, but in recent years many field guides have been turned into apps for ones phone, or other device. Generally, these resources are designed to be brought into the *field,* and used to distinguish species or objects from each other. Field guides are often very specific to a geographic location, so it is important to choose one that is relevant to your surrounding area.

For field guides of plants and animals, they are made up of a series of *species accounts*, one for each species. The type of information that each book contains about each species varies, but they often include the common name, scientific name, species information (habitat, field marks, behaviours), pictures, size, appearance (colouration, shape, etc.) and field marks for identification, and range maps. In field guides of mammals, information about their dental formula and skull identification are often included. The information in the field guides are meant to assist the reader identify the species they are looking at in the field.

Many field guides are arranged according to established taxonomic orders. This means that species that are closely related to each other are found together. For example, all species in the hawk family (Accipitridae) are found in one section of the guide, all species of the woodpecker family (Picidae) are in another, and so on.

It is quite common for field guides to have an index that includes both common and scientific names. The index is often sorted by the first common name, last common name, or scientific names. Other guides may be sorted by larger taxonomic groups but they may also be divided by physical characteristics. An example can be seen below:

Insects: Class Insecta
- Bristletails: Order Thysanura................................62
- Springtails: Order Collembola...............................65
- Mayflies: Order Ephemeroptera............................68
- Dragonflies and Damselflies: Order Odonata...........76

It is common for field guides to contain dichotomous keys, like described above. These keys can be used in combination with species descriptions to help the reader more accurately identify things in nature.

NATURALIST APPS

In the age of mobile technology, apps have been developed to help anyone in the field. Apps can function as field guides, navigation tools, help with citizen science, and more! We have highlighted a few of the more common apps to get you started!

INATURALIST

"iNaturalist is an online social network of people sharing biodiversity information to help each other learn about nature."

iNaturalist is an app that helps you identify animals and plants around you. It also allows you to record and share these observations. By recording this location data, the user (citizen scientist) helps provide research quality data for scientists around the world. Scientists have used this crowdsourced data in conservation efforts and scientific publications.

GO WILD MANITOBA!

Go Wild Manitoba! is a citizen-science monitoring effort that is designed to gather scientific data on species of concern in Manitoba by involving volunteers of all ages and interest levels. Collected data is then sent to biologists who use the information to gain a better understanding of the status and management needs of various species. It is made in association with iNaturalist.org and NatureServe.

EBIRD

The eBird app takes inputed bird sightings and creates data for science and conservation. It is a citizen science online database of bird observations that provides scientists, researchers and amateur naturalists with data about bird distribution and abundance. It allows the research to find more birds around them, share their sightings with the birding community, and track your own lists of birds you have observed. It was created by the Cornell Lab of Ornithology and Audubon. It is now also supported by the National Science Foundation (USA), Wolf Creek Charitable Foundation, and Leon Levy Foundation.

MERLIN BIRD ID

Merlin Bird ID aims to be a *birding coach*, targeted at beginning and intermediate bird watchers. The app will ask you similar questions to an expert birder in order to identify the mysterious bird you just saw or you are looking at. It will ask your date and location as part of the process, and input this data into eBird, where this data is shared with over 800 million other bird sightings around the world. Merlin will also ask you to describe the bird's colour, size, and behaviour. The app then will produce a shortlist of possible species that fit this description. The app also has a photo ID function, that allows the user to input a picture and produce suggested identification. This app is produced by the Cornell Lab of Ornithology.

Merlin Bird ID
From the Cornell Lab of Ornithology
http://bit.ly/MerlinApp

EBUTTERFLY

eButterfly is a citizen science online database of butterfly observations. It collects data on butterfly abundance, distribution, and phenology. It also collects a photo repository of butterfly photos.

LEAFSNAP: AN ELECTRONIC FIELD GUIDE

Leafsnap is a app that helps identify tree species from photographs of their leaves. It also is a series of electronic field guides and has images of tree flowers, fruits, petioles, seeds, and bark. It includes trees found in the Northeastern United States and Canada. This app was developed by researchers at Columbia University, University of Maryland, and the Smithsonian Institution. Leafsnap has recently expanded their app to include the trees of Canada through collaboration with the Canadian Wildlife Federation.

HOW TO READ A SCIENTIFIC PAPER

The following article, written by acclaimed science writer Carl Zimmer, appeared in the New York Times on June 1, 2020.

How You Should Read Coronavirus Studies, or Any Science Paper

Published scientific research, like any piece of writing, is a peculiar literary genre.

By Carl Zimmer

A lot of people are reading scientific papers for the first time these days, hoping to make sense of the coronavirus pandemic. If you're one of them, be advised the scientific paper is a peculiar literary genre that can take some getting used to. And also bear in mind that these are not typical times for scientific publishing.

It is hard to think of another moment in history when so many scientists turned their attention to one subject with such speed. In mid-January, scientific papers began trickling out with the first details about the new coronavirus. By the end of the month, the journal Nature marveled that over 50 papers had been published. That number has swelled over the past few months at an exponential rate, fitting for a pandemic.

The National Library of Medicine's database at the start of June contains over 17,000 published papers about the new coronavirus. A website called bioRxiv, which hosts studies that have yet to go through peer review, contains over 4,000 papers.

In earlier times, few people aside from scientists would have laid eyes on these papers. Months or years after they were written, they'd wind up in printed journals tucked away on a library shelf. But now the world can surf the rising tide of research on the new coronavirus. The vast majority of papers about it can be read for free online.

But just because scientific papers are easier to get hold of doesn't mean that they are easy to make sense of. Reading them can be a challenge for the layperson, even one with some science education. It's not just the jargon that scientists use to compress a lot of results into a small space. Just like sonnets, sagas and short stories, scientific papers are a genre with its own unwritten rules, rules that have developed over generations.

The first scientific papers read more like letters among friends, recounting hobbies and oddities. The first issue of the Philosophical Transactions of the Royal Society, published on May 30, 1667, included brief dispatches with titles such as "An account of the improvement of optick glasses," and "An account of a very odd monstrous calf."

When natural philosophers sent their letters to 17th-century journals, the editors decided whether they were worth publishing or not. But after 200 years of scientific advances, Victorian scientists could no no longer be experts on everything. Journal editors sent papers to outside specialists who understood the details of a particular branch of research better than most scientists.

By the mid-1900s, this practice evolved into a practice known as peer review. A journal would publish a paper only after a panel of outside experts decided it was acceptable. Sometimes the reviewers rejected the paper outright; other times they required the fixing of weak points — either by revising the paper or doing additional research.

Along the way, scientific papers also developed a distinctive narrative arc. A paper published in Philosophical Transactions today is no longer a gossipy letter, but a four-part story. Papers typically open with some history, giving a justification for the new research they contain. The authors then lay out the methods they used to carry out that research — how they eavesdropped on lions, how they measured chemicals in Martian dust. Then the papers present results, followed by a discussion of what those results mean. Scientists will typically point out the shortcomings in their own research and offer ideas for new studies to see if their interpretations hold water.

As a science writer, I've been reading scientific papers for 30 years. I'd guess that I've read tens of thousands of them, in search of new advances to write about, or to do background research for stories. While I'm not a scientist myself, I've gotten pretty comfortable navigating around them.

One lesson I've learned is that it can take work to piece together the story underlying a paper. If I call scientists and simply ask them to tell me about what they've done, they can offer me a riveting narrative of intellectual exploration. But on the page, we readers have to assemble the story for ourselves.

Part of the problem may be that many scientists don't get much training in writing. As a result, it can be hard to figure out precisely what question a paper is tackling, how the results answer it and why any of it really matters.

The demands of peer review — satisfying the demands of several different experts — can also make papers even more of a chore to read. Journals can make matters worse by requiring scientists to chop up their papers in chunks, some of which are exiled into a supplementary file. Reading a paper can be like reading a novel and realizing only at the end that Chapters 14, 30, and 41 were published separately.

The coronavirus pandemic now presents an extra challenge: There are far more papers than anyone could ever read. If you use a tool like Google Scholar, you may be able to zero in on some of the papers that are already getting cited by other scientists. They can provide the outlines of the past few months of scientific history — the isolation of the coronavirus, for example, the sequencing of its genome, the discovery that it spreads quickly from person to person even before symptoms emerge. Papers like these will be cited by generations of scientists yet to be born.

Most won't, though. When you read through a scientific paper, it's important to maintain a healthy skepticism. The ongoing flood of papers that have yet to be peer-reviewed — known as preprints — includes a lot of weak research and misleading claims. Some are withdrawn by the authors. Many will never make it into a journal. But some of them are earning sensational headlines before burning out in obscurity.

In April, for example, a team of Stanford researchers published a preprint in which they asserted that the fatality rate of Covid-19 was far lower than other experts estimated. When Andrew Gelman, a Columbia University statistician, read their preprint, he was so angry he publicly demanded an apology.

“We wasted time and effort discussing this paper whose main selling point was some numbers that were essentially the product of a statistical error,” he wrote on his blog.

But just because a paper passes peer review doesn’t mean it’s above scrutiny. In April, when French researchers published a study suggesting that hydroxychloroquine might be effective against Covid-19, other scientists pointed out that it was small and not rigorously designed. In May, a much bigger paper was published in the Lancet suggesting that the drug could increase the risk of death. A hundred leading scientists published an open letter questioning the authenticity of the database on which the study relied.

When you read a scientific paper, try to think about it the way other scientists do. Ask some basic questions to judge its merit. Is it based on a few patients or thousands? Is it mixing up correlation and causation? Do the authors actually present the evidence required to come to their conclusions?

One shortcut that can sometimes help you learn how to read a paper like a scientist is by making judicious use of social media. Leading epidemiologists and virologists have been posting thoughtful threads on Twitter, for example, laying out why they think new papers are good or bad. But always make sure you’re following people with deep expertise, and not bots or agents of disinformation peddling conspiracy nonsense.

Science has always traveled down a bumpy road. Now it is in an extraordinary rush, with the world looking for every new preprint and peer-reviewed paper in the hope that some clue will emerge that helps save millions of lives.

Yet our current plight does not change the nature of the scientific paper. It’s never a revelation of absolute truth. At best, it’s a status report on our best understanding of nature’s mysteries.

For some step by step guides on how to read a scientific paper, please see the article below produced by Dr. Jennifer Raff, assistant professor at the University of Kansas, in the department of Anthropology.

How to read and understand a scientific article

Dr. Jennifer Raff

To form a truly educated opinion on a scientific subject, you need to become familiar with current research in that field. And to be able to distinguish between good and bad interpretations of research, you have to be willing and able to read the primary research literature for yourself. Reading and understanding research papers is a skill that every single doctor and scientist has had to learn during graduate school. You can learn it too, but like any skill it takes patience and practice.

Reading a scientific paper is a completely different process from reading an article about science in a blog or newspaper. Not only do you read the sections in a different order than they're presented, but you also have to take notes, read it multiple times, and probably go look up other papers in order to understand some of the details. Reading a single paper may take you a very long time at first, but be patient with yourself. The process will go much faster as you gain experience.

The type of scientific paper I'm discussing here is referred to as a primary research article. It's a peer-reviewed report of new research on a specific question (or questions). Most articles will be divided into the following sections: abstract, introduction, methods, results, and conclusions/interpretations/ discussion.

Before you begin reading, take note of the authors and their institutional affiliations. Some institutions (e.g. University of Texas) are well-respected; others (e.g. the Discovery Institute) may appear to be legitimate research institutions but are actually agenda-driven.

Tip: google "Discovery Institute" to see why you don't want to use it as a scientific authority on evolutionary theory.

Also take note of the journal in which it's published. Be cautious of articles from questionable journals, or sites that might resemble peer-reviewed scientific journals but aren't (e.g. Natural News).Yet our current plight does not change the nature of the scientific paper. It's never a revelation of absolute truth. At best, it's a status report on our best understanding of nature's mysteries.

Step-by-Step Instructions for Reading a Primary Research Article

1. **Begin by reading the introduction, not the abstract.**
   The abstract is that dense first paragraph at the very beginning of a paper. In fact, that's often the only part of a paper that many non-scientists read when they're trying to build a scientific argument. (This is a terrible practice. Don't do it.) I always read the abstract last, because it contains a succinct summary of the entire paper, and I'm concerned about inadvertently becoming biased by the authors' interpretation of the results.

2. **Identify the *big* question.**
   Not "What is this paper about?" but "What problem is this entire field trying to solve?" This helps you focus on why this research is being done. Look closely for evidence of agenda-motivated research.

3. **Summarize the background in five sentences or less.**
   What work has been done before in this field to answer the big question? What are the limitations of that work? What, according to the authors, needs to be done next? You need to be able to succinctly explain why this research has been done in order to understand it.

4. **Identify the specific question(s).**
   What exactly are the authors trying to answer with their research? There may be multiple questions, or just one. Write them down. If it's the kind of research that tests one or more null hypotheses, identify it/them.

5. **Identify the approach.**
   What are the authors going to do to answer the specific question(s)?

6. **Read the methods section.**
   Draw a diagram for each experiment, showing exactly what the authors did. Include as much detail as you need to fully understand the work.

7. **Read the results section.**
   Write one or more paragraphs to summarize the results for each experiment, each figure, and each table. Don't yet try to decide what the results mean; just write down what they are. You'll often find that results are summarized in the figures and tables. Pay careful attention to them! You may also need to go to supplementary online information files to find some of the results. Also pay attention to:
   - The words "significant" and "non-significant." These have precise statistical meanings.
   - Graphs. Do they have error bars on them? For certain types of studies, a lack of confidence intervals is a major red flag.
   - The sample size. Has the study been conducted on 10 people, or 10,000 people? For some research purposes a sample size of 10 is sufficient, but for most studies larger is better. 8.

8. **Determine whether the results answer the specific question(s).**
   What do you think they mean? Don't move on until you have thought about this. It's OK to change your mind in light of the authors' interpretation -- in fact, you probably will if you're still a beginner at this kind of analysis -- but it's a really good habit to start forming your own interpretations before you read those of others.

9. **Read the conclusion/discussion/interpretation section.**
   What do the authors think the results mean? Do you agree with them? Can you come up with any alternative way of interpreting them? Do the authors identify any weaknesses in their own study? Do you see any that the authors missed? (Don't assume they're infallible!) What do they propose to

to do as a next step? Do you agree with that?

10. **Go back to the beginning and read the abstract.**
    Does it match what the authors said in the paper? Does it fit with your interpretation of the paper?

11. **Find out what other researchers say about the paper.**
    Who are the (acknowledged or self-proclaimed) experts in this particular field? Do they have criticisms of the study that you haven't thought of, or do they generally support it? Don't neglect to do this! Here's a place where I do recommend you use Google! But do it last, so you are better prepared to think critically about what other people say.

A full-length version of this article originally appeared on the author's personal blog (www.violentmetaphors.com). She gratefully acknowledges Professors José Bonner (Indiana University) and Bill Saxton (UC Santa Cruz) for teaching her how to read scientific papers using this method.