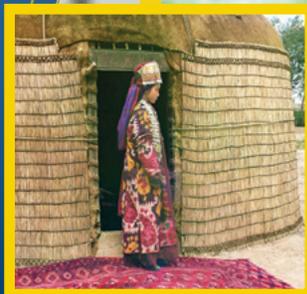


# NORTH STAR GEOGRAPHY



**By Tyler H. Hogan**



Dover, Delaware

## North Star Geography

Text © 2014 by Tyler H. Hogan & Bright Ideas Press

Library of Congress Control Number: 2014905025

ISBN: 978-1-892427-52-6 (Hardback Reader)

978-1-892427-53-3 (E-book Reader)

978-1-892427-54-0 (E-book *Companion Guide*)

First Edition

Bright Ideas Press

Dover, Delaware

[www.BrightIdeasPress.com](http://www.BrightIdeasPress.com)

877.492.8081

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Cover design: Brian Peters, Noah's Art ([www.Level2Creative.com](http://www.Level2Creative.com))

Interior design: David Borrink ([www.ArtsAndLetters.biz](http://www.ArtsAndLetters.biz))

Editing: Mary Jo Tate ([www.WriteAGreatBook.com](http://www.WriteAGreatBook.com))

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***For my daughters: Kaylee, Avalon, and Sierra***

*May you find God's world fascinating and beautiful,  
and may you worship its creator with all of your hearts.*

“It’s a dangerous business, Frodo, going out of your door. You step into the Road, and if you don’t keep your feet, there’s no knowing where you might be swept off to.”

– Bilbo Baggins, *The Fellowship of the Ring* by J. R. R. Tolkien

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# Preface

I love geography. Some of my fondest childhood memories involve poring over my family's atlases, creating maps of worlds real and imagined, and finding places on our big world map during our dinner conversations. It has always been a part of my life. I started doing professional cartography work when I was 14, and I've been developing a deeper appreciation and understanding for the art and science behind maps.

Geography asks the question "Where?" But that question is always just the beginning of the story. "What?" "Why?" and "How?" inevitably follow. The more we study *where*, the more we want to know about the other questions too. The paths of inquiry go on indefinitely, each road displaying something of the glory of God we have never seen before. When I study geography, I feel like I'm getting an inside look at what God has done (and is doing) in the world.

Sadly, many of the parents and teachers I talk with feel unequipped to teach geography, especially at the high school level. Or worse, they find geography boring themselves and can't possibly expect their students to be interested! As a result, they gloss over geography and then feel inadequate about their students' education and their abilities as teachers.

I wrote this book because I love geography, I love seeing God's hand in His creation, and I want others to experience it with the awe and joy that I do. I want more people to give thought to the world and care about their role in it. I hope this book helps you love geography more and see God more clearly too.

# Acknowledgments

This book would never have been published without the help of many wonderful people. I'd like to offer my sincerest thanks to Helen Hogan, Milton and Kylie Wilcox, Hannah Eagleson, Ryan Brown, Audrey Moore, Mary Jo Tate, Stacey Lane, the students of Blue Heron Learning Center, and my coworkers at Bright Ideas Press. This book wouldn't be here without all you contributed. Thank you to Dr. Jay Wile, who graciously permitted me to print an interview with him on climate change. Thanks also to my parents, Bob and Maggie Hogan, who gave me the tools to learn anything and who provide valuable feedback on all of my projects.

# Teacher's Introduction

Geography is one of the most undertaught subjects in schools, but in an increasingly global-minded world, it is one of the most crucial topics for us to understand. The study of the earth, its structure, and its inhabitants informs just about everything we do every day. While it is a very broad subject, we can divide geography into three primary categories. In this course, we will study each of these three topics in order:

- **Geography skills** include reading maps; using geographic tools like compasses, GPS, and atlases; and understanding topics like cartography, surveying, and navigation. (Lessons 1–3)
- **Physical geography** is similar to earth sciences. It includes studies in geology, meteorology, oceanography, ecology, hydrology, and astronomy. Roughly, it studies the four spheres of the earth: the *lithosphere*, the *hydrosphere*, the *atmosphere*, and the *biosphere*. (Lessons 4–9)
- **Human geography** looks at mankind and how we relate to our location and environment. It includes topics such as sociology, culture, religion, transportation, agriculture, government, and economics. (Lessons 10–16)

Clearly, these are topics which cannot be covered exhaustively in a single year. This course is an overview of world geography, not a doctoral program. But I hope that by the end, it will have whetted your appetite for learning about the world in which you live.

Before you delve in, please take a few minutes to read through this introduction, as I think you will find it very helpful in planning your studies.

## Course Structure and Assignments

There are many ways to study geography, and no one way is best. Here is an overview of what's included and some of the scheduling options that may work for you. All of these tools (except the lesson text) are included in the accompanying *Companion Guide* on CD.

Please note: There is more in this program than any one family should attempt! I have intentionally provided many different study tools to meet the needs of students with a wide variety of learning styles and backgrounds in geography. It is up to you as the teacher to decide which assignments would be most appropriate and feasible for your students and setting. Unless you're teaching a college-prep class to aspiring geographers, please don't do it all! I would hate for your geography studies to be a source of frustration or burnout. Don't overwhelm yourself—instead, have fun learning and pursuing the topics you and your students find most interesting.

## ***The Student Reader***

This book contains 16 lessons, usually around 10–15 pages apiece. The lesson text is geared toward junior high and high school students, so if you're teaching younger children, summarize or read aloud as you see fit. The lessons address high-level geographic concepts; the green sidebars highlight concrete examples of selected concepts and introduce students to places of interest or importance around the world. The hardest part of writing this curriculum was deciding what *not* to include. So many interesting places, facts, and stories are worth discovering, though many of them don't fit neatly into the scope and sequence of a curriculum.

## ***Hands-On Activities***

Each lesson includes several options for hands-on projects. Some are short and simple, while others are more involved. Make sure you look ahead and plan which activities you want to do based on the time you have available and your students' learning styles.

Each activity that requires anything other than a pencil and paper or an Internet connection lists the needed materials. I have tried to keep the materials list as simple and inexpensive as possible. Some require a **graphic organizer**, all of which are provided in the *Companion Guide*.

While almost all of the activities could be done solo, there are a few which would be much better in a group setting. If you're doing this program outside of a classroom or co-op setting, you may want to gather some friends to get the most out of those projects.

## ***Building Your Own Atlas***

When I was about 5 years old, I wanted to make a special Father's Day gift for my dad. I asked my mom for an atlas and a stack of tracing paper. For several days, I sat at my desk, tracing each continent, including the country names and borders. By Father's Day, I had made a small atlas to give my dad. I couldn't read half the words I had traced, but I had a blast doing it.

In the **atlas building** segment of each lesson, students are going to do something similar by labeling outline maps (maps with no words or labels). This will help them become familiar with each continent's countries and important physical features. The process of looking up each feature and labeling it on a map is a good exercise for multiple learning styles. Filling out fact files periodically complements the map work. (See the section on **graphic organizers** below.) The assignments cover each continent and create a lovely set of political, physical, and thematic maps.

Outline maps for each continent are provided in the *Companion Guide*. While reference maps are also included in the *Companion Guide*, I recommend using an atlas such as the WonderMaps software or (if you prefer paper) *Rand McNally's Atlas of World Geography* as your primary reference. This is a good opportunity to learn to use a gazetteer, so please don't just Google each location, except as a last resort.

## ***Note-Taking Pages***

Taking notes in class is an important skill, especially for college-bound students. To help build that skill, each lesson includes a note-taking page with 10 questions taken from the text. These pages should be printed out and either filled in while reading the text or used to review the lesson material later on. The majority of questions are short answer and include key vocabulary terms. Later lessons include a few open-ended reflection questions.

The note-taking pages also serve as the study guide for the quizzes (which include the same 10 questions verbatim) and the final exam, which includes several questions from each lesson's notes.

## ***Memorization Lists***

Part of being well-versed in geography is knowing (at least generally) where things are—especially countries, world regions, and important physical features. The *Companion Guide* includes a list of 198 countries<sup>1</sup> and 70 regions and physical features worth memorizing. I recommend learning them at a rate of roughly 16 items per lesson, and I have broken them down by region and separated the political from the physical features. I have *not* included capital cities in the lists, as that goes well beyond the intended goal of *general* geographic literacy. However, if you want your students to memorize those as well, I'm sure you'll have little trouble compiling a list.

---

1. The number of countries in the world is a matter of much debate. I have chosen to include the 193 member states of the United Nations, as well as a few select nonmembers and observers. Because some areas of the world are claimed by multiple nations, I had to make choices about how certain areas are labeled on the maps and in the text. In such cases, I have tried to take as politically neutral a stance as possible. Also, the boundaries and names of countries can change overnight, so while I strove for accuracy, some things may become out of date.

## ***Research Questions***

The *Companion Guide* includes a set of questions for each continent designed to stimulate further study and give students a chance to practice their investigative skills. A simple search online will suffice to answer most of the questions, though some may require a bit more digging. These also serve as an opportunity to discuss with your students how to conduct proper research online, how to determine if a source is credible or authoritative, and the proper and safe use of search terms. Answers to the research questions are provided in the *Companion Guide*. (See the “Reference List” section below.)

## ***Quizzes and Tests***

There is a quiz for each lesson in the *Companion Guide*. The first page of the quiz always contains the 10 questions from that lesson’s note-taking page. The pages after that are map work based on the memorization lists from that lesson. They require students to match the names of countries or physical features (given in a word bank) with their locations on a map.

If you elect not to use the memorization component in your study, I recommend using only the first page of the quiz, which is related strictly to the lesson text.

The final exam includes questions taken from all 16 of the lessons. The map section includes only physical features that everyone should know—no country names are included. This is to make it possible for students to complete the final if they have not done the memorization during the year, but *have* done the atlas building section.

Answer keys for the quizzes and final, as well as grading rubrics, are also in the *Companion Guide*.

## ***Vocabulary***

Each lesson includes vocabulary words in **bold**. Definitions are provided in the glossary at the end of the book, which doubles as an index by providing lesson numbers. The *Companion Guide* includes another glossary, arranged by lesson instead of alphabetically.

How you wish to incorporate vocabulary is entirely up to you. Many of the 450+ terms will already be familiar to your students, so feel free to skip the easy ones altogether. You may wish to have students create their own glossary, make flash cards, or even illustrate the remaining unfamiliar terms. Students with artistic interests may enjoy building a visual glossary by drawing a picture or finding an image online that defines the term. For example, they may paste a photograph of the Sahara under *desert* or draw a picture of a crowded street under *population density*. They may find it much easier to put this together on a computer than in a notebook.

Because there are so many terms and since many of them are unique to geography (you’re not likely to see *Lehmann discontinuity* or *celestial navigation* on the SAT), I encourage you not to spend too much time on the vocabulary.

## ***Graphic Organizers***

The graphic organizers section of the *Companion Guide* includes:

- **World/Continent Fact Files** are to be filled out as part of the atlas building exercises. They ask basic questions about human and physical geography and can be filled out with the aid of a good atlas, almanac, or web search. Students shouldn't feel the need to answer every single question if they can't find good data.
- **Country Fact Files** are an optional part of the atlas building assignments. While they make a good springboard for studying individual nations, students shouldn't get bogged down doing them. In fact, you can even use them solely as extra credit options or as a way to make up points from countries that students mislabeled on their quizzes.
- **Cultural Treasure Fact File** is used in the lessons on culture.
- **Elected Officials** pages and a **Candidate Comparison** page are used in the lesson on government.
- **Regional Geography Fact Files** include questions on both physical geography and human geography and are to be used in conjunction with the final lesson's project. Blank pages are provided for other data students may find in their research, maps and pictures they collect, and citing sources. I have also included an example of a completed final project, complete with sources.

## ***Reference List***

I have included a reference list in the back of this reader. It includes sources I have used, valuable websites and books, and other options for further study. Lesson 16 includes a section on research and finding valuable sources, which may be worth previewing. The research questions, fact files, and final regional geography project require students to make good use of available research sources.

Of course, as with all materials, it is up to you as a teacher to gauge how well these resources align with your worldview and discern how appropriate the material is for your students. Geography touches on so many subjects, some of which are controversial (such as the age of the earth), sensitive (like issues of poverty or injustice), or politically charged (such as environmental policy). My hope is that you will find these materials useful and that they will spark great conversations, whether or not you share their perspective or convictions.

---

## Schedule Options

There are many ways to schedule *North Star Geography*. Most people will try to finish the course in one year, while others may need to spread it out over two years or slim it down to a single semester. Here are some ideas on how that might work.

### ***One Year: 32 Weeks***

This is the standard five-days-per-week schedule. It assumes you're doing everything in the book and companion guide and want to spend two weeks per lesson.

	<b>Monday</b>	<b>Tuesday</b>	<b>Wednesday</b>	<b>Thursday</b>	<b>Friday</b>
<b>Week 1</b>	Read the Lesson	Atlas Building	Atlas Building OR Research Questions	Fill Out Fact File(s)	Memorization
<b>Week 2</b>	Note-Taking Page & Vocabulary	Activities	Activities	Activities	Take the Quiz

This is a fairly intense schedule, suitable for academically advanced students in their junior or senior year. The average high school or junior high student should not try to do everything on this list. Depending on your teaching priorities, you could easily trim this in the following ways:

- Skip the memorization lists and use only the first page of each quiz.
- Skip the vocabulary.
- Skip the research questions.
- Skip the fact files.
- Skip the thematic maps.

I recommend against skipping the note-taking pages or the political and physical maps in the atlas building section. Those are the heart of the program and should be prioritized.

## ***Two Years: 64 Weeks***

This schedule takes three days per week for 64 weeks over two years. Each lesson takes four weeks, so it's a much more relaxed pace. It works out that your first year is spent primarily on physical geography, while your second year focuses on human geography.

	<b>Monday</b>	<b>Tuesday</b>	<b>Wednesday</b>	<b>Thursday</b>	<b>Friday</b>
<b>Week 1</b>	Read the Lesson		Atlas Building		Memorization
<b>Week 2</b>	Note-Taking Page		Activities		Memorization
<b>Week 3</b>	Fact File		Atlas Building OR Research Questions		Memorization
<b>Week 4</b>	Vocabulary		Activities		Quiz

Like the one-year schedule, it includes all of the elements of the program, so feel free to trim as best meets your needs. For the average student, it's much more realistic to do everything over two years. This is an especially good option for students in grades 7–10.

## ***One Semester: 16 Weeks***

This option is limited to the bare bones of the program. Because it cuts out the memorization, research questions, vocabulary, and thematic maps; makes the fact files optional; and quizzes students only on the content of the lessons, it would be appropriate for a half-credit of high school geography rather than a full credit. Two days are reserved for activities, though the second day could be used as a study day or catch-up day.

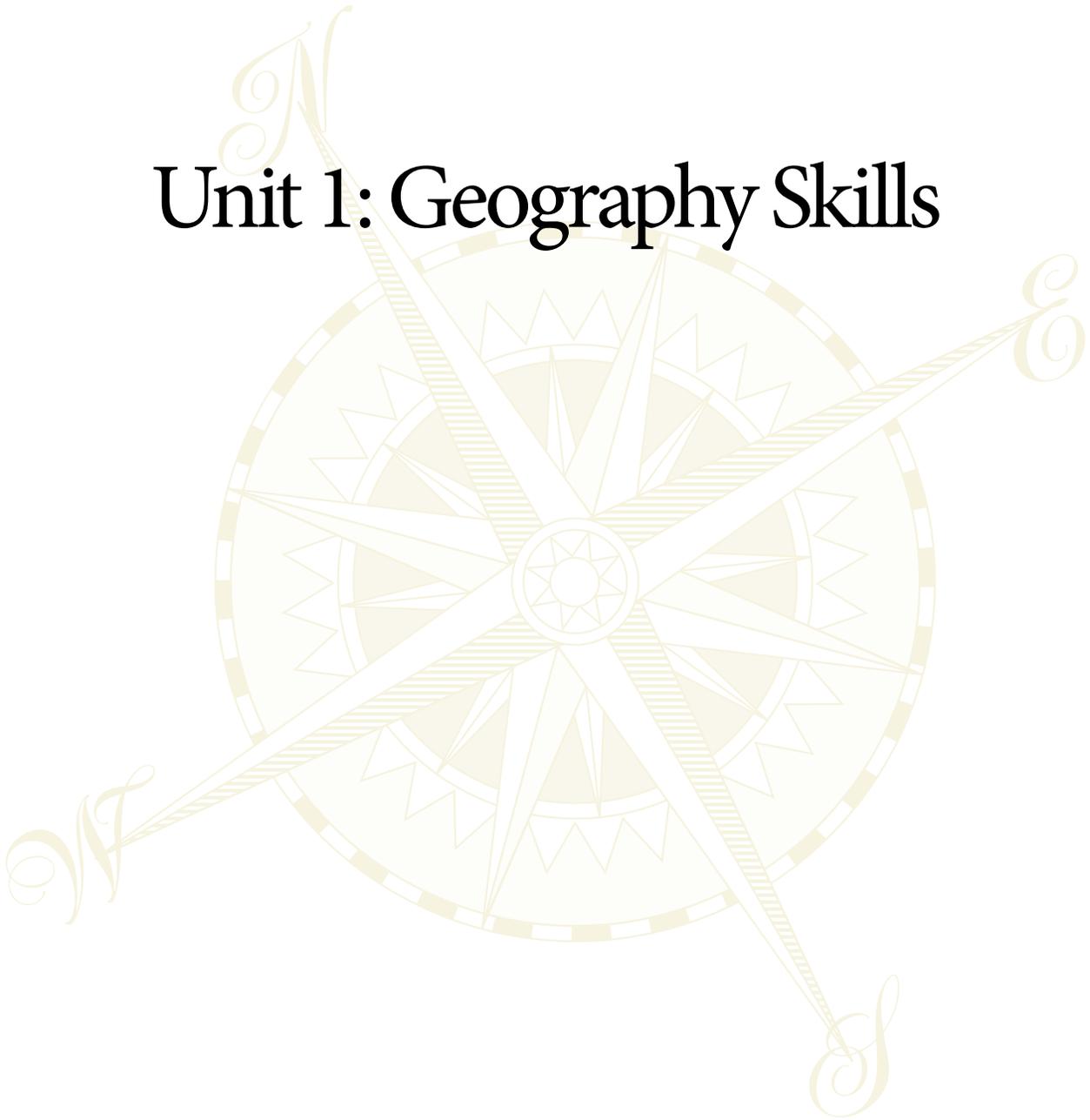
	<b>Monday</b>	<b>Tuesday</b>	<b>Wednesday</b>	<b>Thursday</b>	<b>Friday</b>
<b>Week 1</b>	Read Lesson and Take Notes	Atlas Building	Activities	Activities OR Fact File	Quiz on Lesson (not on maps)

The next few pages are day-by-day schedule grids for each of these three options.



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# Unit 1: Geography Skills



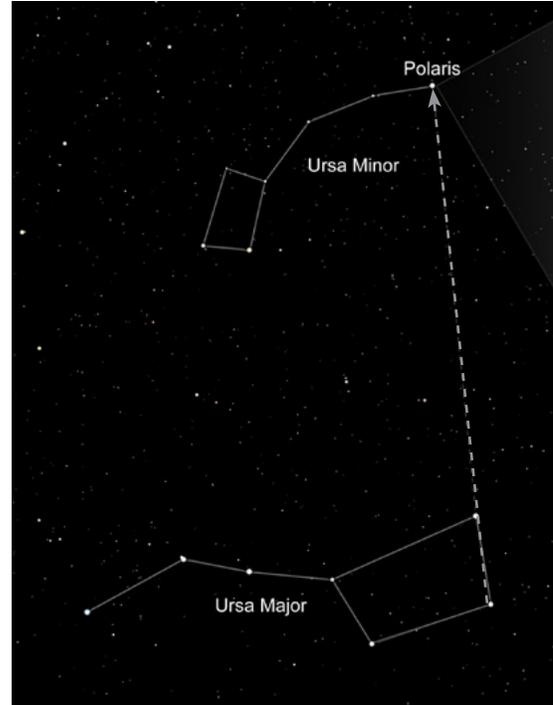
# Lesson 3: Navigation

The study of geography has always been intertwined with the study of navigation. To ask “What’s out there?” leads to asking “How do I get there?” In lesson 2 we looked at one of the most important concepts of navigation: direction. In this lesson we’ll look at its twin: position. Establishing direction and position is the basis of navigation.

By using a compass, you can establish direction anywhere in the world using the North or South Pole as a reference point. But what reference points could be used to determine position? The one reference point that everyone has in common all over the world is the sky—specifically the sun, moon, and stars. Astronomers and navigators worked together to develop a method known as **celestial navigation**, which can be used to plot your position anywhere in the world in terms of latitude and longitude by measuring the positions of celestial bodies like the sun and the North Star. Celestial navigation has been used in different forms since the days of the ancient Greeks and is still taught today as an alternative method to GPS technology, especially in the navy.

## *Sailing by the Stars*

Conveniently, explorers could measure latitude at night by measuring how many degrees above the horizon the **North Star (Polaris)** appeared. At the North Pole, Polaris is directly overhead— $90^\circ$  from the horizon. At, say,  $30^\circ$  north, Polaris is  $30^\circ$  above the horizon line. On the equator, Polaris is practically on the horizon—about  $0^\circ$ . For this reason, we call Polaris the celestial North Pole (as opposed to the geographic North Pole, where lines of longitude intersect, or the magnetic North Pole where your compass points.) Below the equator, Polaris is no longer visible, and the **Southern Cross** constellation must be used instead to find the celestial South Pole. Alternately, a navigator could use the position of the sun at noon and an almanac to calculate latitude during the day. This method is somewhat more complicated because the angle of the sun in the sky varies with the seasons (requiring an almanac to be accurate).

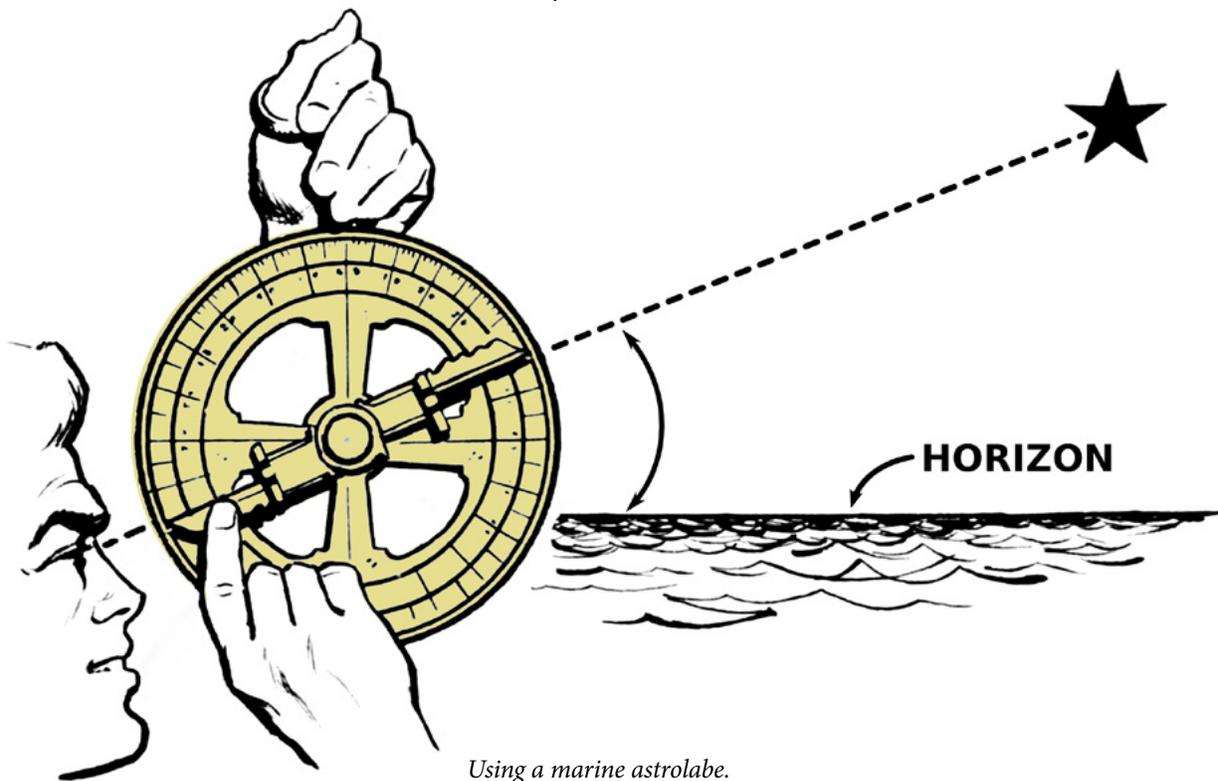


*Polaris is the tip of the handle of Little Dipper (Ursa Minor) and can be found by tracing a line from the two edge stars of Ursa Major (the Big Dipper).*

As mentioned earlier, before the invention of the marine chronometer, there was no entirely accurate or convenient way to measure longitude at sea. The methods that did exist often required complex trigonometry or impossibly accurate measurements. Some methods were based on the distance of the moon, or of Jupiter's moons, or measuring the east/west "drift" of stars from one night to the next. But without an expert astronomer onboard, none of these methods were particularly practical. The marine chronometer made longitude calculation easy and accurate. Every hour of difference between your time and Greenwich time was a difference of  $15^\circ$  east or west. Every minute difference was  $\frac{1}{4}^\circ$  difference, etc.

### *The Tools of the Trade*

While the main tool for establishing direction (the compass) hasn't greatly changed since its invention, tools for measuring position have gone through great changes. The original tool for seafarers was called a **marine astrolabe**. This astrolabe was a circle, held by a ring at the top, with a movable sight. To use it, the navigator would hold the instrument by the ring at the top (so that it would be level) and find the star he wanted in the sight. The astrolabe was marked off in degrees around the whole circle, like a protractor or compass. The angle of the sight would tell him the angle of the star relative to the horizon. (See the image below.) With that knowledge he could calculate his position. Often, a navigator would take sightings of the sun and/or multiple stars and consult his reference books for extra accuracy.



*Using a marine astrolabe.*

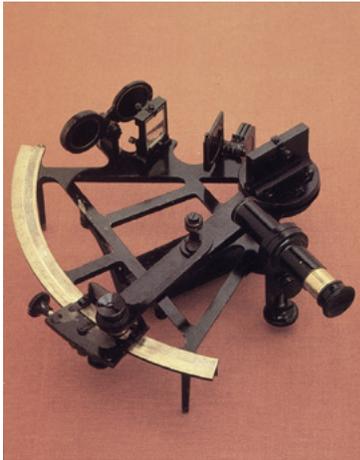
*The angle between the horizon and Polaris is your latitude (in the Northern Hemisphere).*

Many variations on the marine astrolabe were constructed over time, including these:

- **quadrant** (1500–1700s) — This instrument was one-fourth of a circle, with a longer sight that allowed for increased accuracy.



*A quadrant*



*A sextant*

- **sextant and octant** (1700s) — These instruments were similar to the quadrant but were only one-sixth and one-eighth of a circle, respectively. They relied on two sights—one for the horizon and another for the sun or stars. The second sight was next to the first and used mirrors, so someone could see both objects at the same time.

- **cross-staff** (1500s) — This instrument consisted of a long pole (the staff) and a movable arm (the cross). The staff would be held straight along the horizon at eye level, and the cross would be moved until a straight line was formed between the eye, the cross, and the sun or star. The staff had degree markings like the astrolabe, and the position of the cross on the staff indicated the angle of the star.
- **backstaff** (1500–1700s) — This was similar to the cross-staff, except the user's back was to the sun. Measuring based on the shadow of the cross on the far end of the staff was preferable to staring directly at the sun while trying to take a reading.



*A cross-staff*

## *Modern Tools*

In the twentieth century, new technologies such as radar, sonar, and satellite communications made determining position much easier. With **radar**, radio waves are bounced off distant objects, and the time it takes them to return is used to calculate the distance. **Sonar** works the same way underwater, using sound waves instead of radio. These calculations are made using computers, making them fast and accurate. While neither radar nor sonar is useful in determining absolute position (such as from a moving boat or plane), they are very useful in determining relative position from fixed landmarks (like lighthouses or air-traffic control towers). In fact, when used in conjunction with good reference points, radar can make very accurate maps (especially elevation maps). Sonar is similarly useful in mapping the ocean floor.

Of course the most common tool used today for determining position is GPS. We'll discuss GPS and satellites later in this lesson.

## *Plotting a Course*

Knowing your position and direction are key parts of navigation. But you also need to establish your route. Where do you turn? What roads do you take? Out of all the possible ways to get there, which is the best?

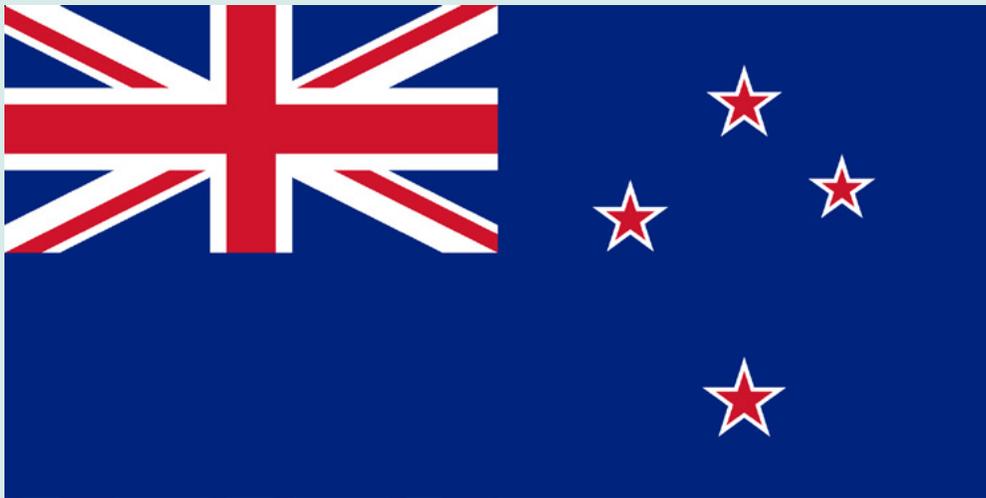
The shortest distance between two points is a straight line. But in navigation, a straight line may not always result in the shortest trip. People generally want to get from here to there as fast as possible. Therefore, when planning a trip, it's important to remember that sometimes it takes less time to go the long way around. For instance, when driving from Philadelphia to Boston, the shortest distance goes right through New York City. Given the high volume of traffic in New York City, possible road closures, accidents, likelihood of getting lost, and other factors, a wise navigator might elect to go out of his way to avoid NYC, thus saving time in the long run.

Getting around can be complicated! Drivers have to think about traffic, pilots take atmospheric conditions and weather into consideration, mariners think through currents and trade winds, and cyclists think about hills and safety issues like visibility and bike lanes. Where will you stop to refuel or spend the night? Do you need to make any other stops along the way? How much money will a trip cost? Whether you're using an astrolabe or a GPS device, a good navigator thinks through all these things.

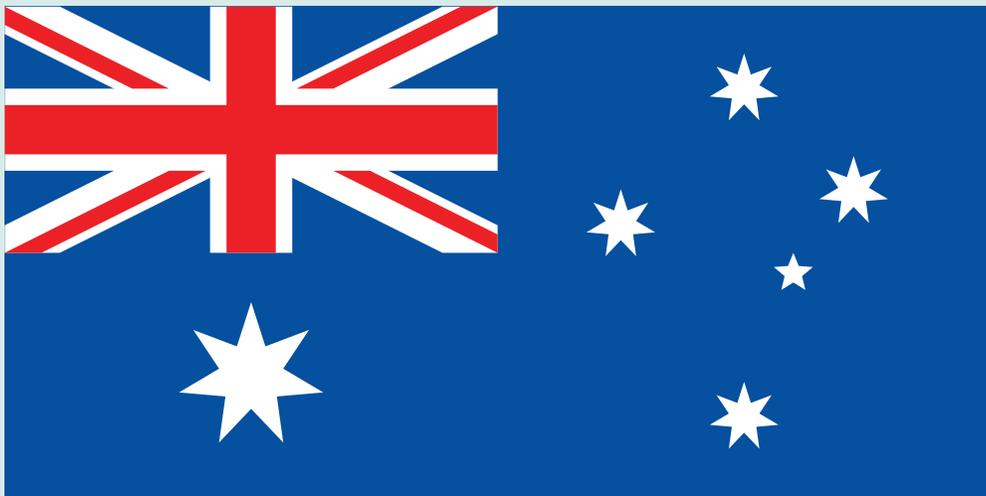
### *The Southern Cross and the New Zealand Flag*

The Southern Cross is an important symbol of the Southern Hemisphere as well as being a helpful guide to navigation. Because the Southern Cross is visible only in the Southern Hemisphere, it is used on the New Zealand flag to represent New Zealand's geographical location.

The New Zealand flag features a blue field with a Union Jack in the top left corner and four red stars on the right side. The Union Jack symbolizes New Zealand's historical links to Great Britain, and the four red stars—arranged in a cross shape—symbolize the Southern Cross and through it New Zealand's placement in the Southern Hemisphere.



*New Zealand's flag*



*Australia's flag uses the Southern Cross constellation for the same reasons as New Zealand, but its stars are white, and they include Epsilon Crucis as well as a seven-pointed commonwealth star under the Union Jack representing the states and territories of Australia.*

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## Lesson 3.2

# Surveying and Mapmaking

So far, we've talked about methods of determining direction (using a compass) and position (latitude and longitude). We've discussed scales and projections and the basics of reading maps and atlases. Let's pull all of that information together and learn how to make a map.

### *The Steps*

The science and art of making maps is called **cartography**. Here are some steps cartographers work through:

#### **Determine Scope**

The first step in drawing a map is determining its scope—what information it will contain. As we've discussed, you can make a map of any size area—from a bedroom to a galaxy. Let's assume you'll do a simple map of your room. As part of determining scope, you should consider what will be visible on the map. It might include:

- walls, doors, and windows
- furniture
- electrical outlets and appliances
- messy zones
- locations of favorite toys, trophies, and memories
- where you want things to be in the future (if you're planning to rearrange)

#### **Gather Data**

Once you know what you want to include, the next step is to gather data. This mostly involves taking measurements. In this case, you'd need to measure the walls, furniture, and placement of included objects. Gathering data may also involve written descriptions that you can represent graphically later. ("The SW corner is the messiest, followed by the NE corner and the entire closet space.") The process of taking the measurements of an area is called **surveying**. In a survey, you establish reference points and measure the direction and distance between them to establish and verify position.

## Draft the Map

Once you have all the relevant data, you can sketch a rough draft of the map. When precision is required, it often helps to work on graph paper. At this point, you'll need to determine your scale and orientation. When mapping small areas, projection generally isn't an issue. Of course, it's important to check your work to verify accuracy. If you made your draft with pencil, you might trace over it with a pen and erase your pencil marks to give it a nice clean look. Don't forget to add a title, scale, and compass rose. When you have a satisfactory map in front of you, it's ready for people to use.

## Geometry

Perhaps the most important part of the process is surveying. Accurate measurements are essential to a useful map. When measurements are not precise, they lead to errors that (depending on the scale of the error) can be disastrous for the end user!

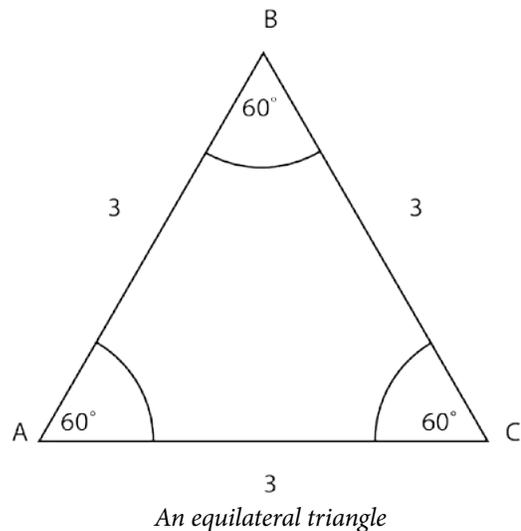
Surveying relies heavily on the sciences of geometry and trigonometry (the study of triangles) to ensure accuracy. If you're not a geometry buff and haven't ever taken trig, don't worry. While a deep knowledge of trigonometry opens up a lot of possibilities for the professional surveyor, you can get by with a few basic facts. The basic idea is that if you know *some* information about a triangle, you can figure out the rest. A calculator may come in handy if you don't like doing a little math in your head.

**Fact 1: In an equilateral triangle, all three sides are the same length, and the angle between them is always  $60^\circ$  each.**

This means that (like the diagram shows), if you know

- Line AC is 3 and
- Angles A, B, and C are  $60^\circ$

then you also know the lengths of lines AB and BC. This is great news for surveyors trying to determine how far away certain things are!



**Fact 2: In a right triangle, the Pythagorean theorem helps us find the length of the hypotenuse.**

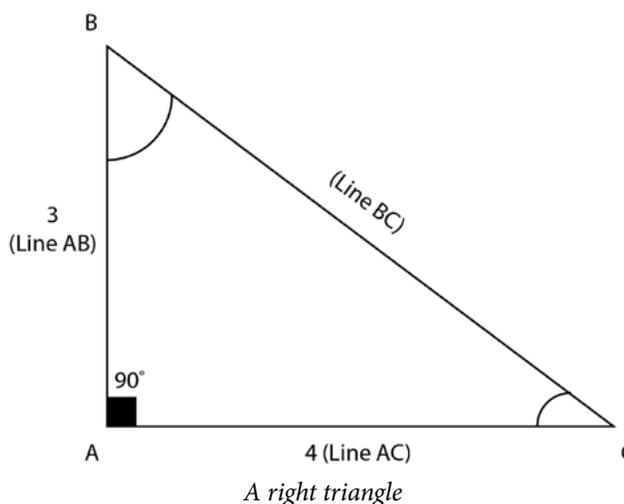
The Pythagorean theorem says that  $AB^2 + AC^2 = BC^2$ .

That means that if we know the lengths of the lines AB and AC, we can

- Square them to find  $AB^2$  and  $AC^2$
- Then add  $AB^2 + AC^2$  to find  $BC^2$
- Then take the square root of  $BC^2$  to find the length of line BC.

In this case:

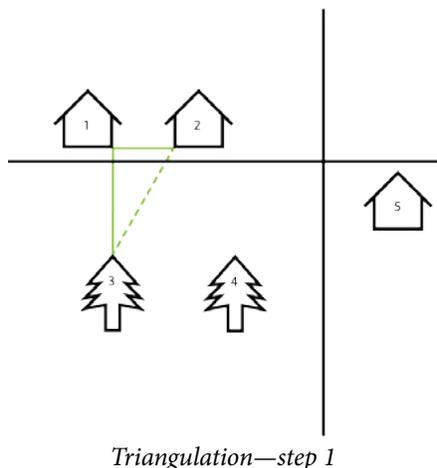
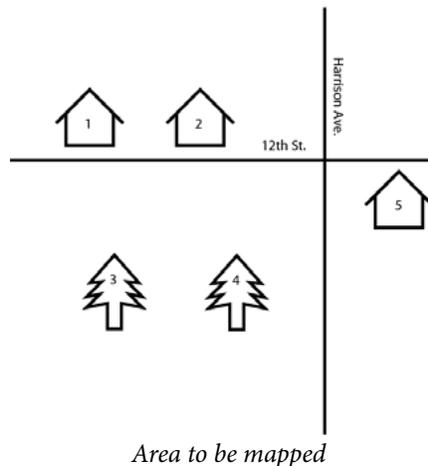
- $3^2 = 9$  and  $4^2 = 16$
- $9 + 16 = 25$
- The square root of 25 is 5, so line BC's length is 5.



### Triangulation

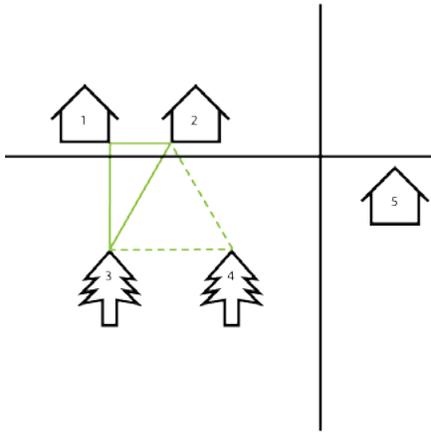
If none of that makes sense, don't worry. You'll learn all about that when you take geometry. As long as you understand that if we know *some* information about a triangle, we can usually figure out the rest, just keep reading.

Here's how surveyors use this information. Let's say a surveyor wants to make a map of the area shown in the figure.



To calculate the position of each of those features, he would start by taking a measurement of a few objects that are easy to measure—in this case, the distances between house 1 and house 2 and between house 1 and tree 3. At each point, he would also measure the angles between three objects. It would look like the figure on the left.

It happens to make a right triangle, which means he can easily calculate the distance between house 2 and tree 3 without measuring it! Now, he has another baseline to work with—the line between house 2 and tree 3.



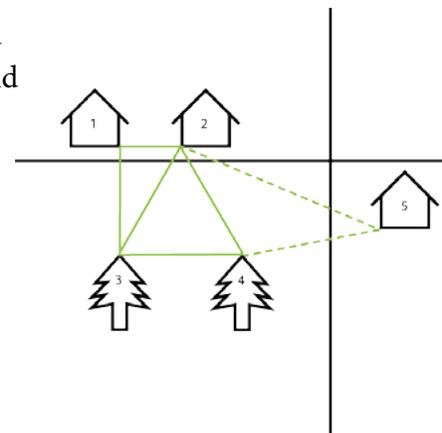
Triangulation—step 2

The surveyor notices that the angles between house 2, tree 3, and tree 4 are all the same:  $60^\circ$ . That means it's an equilateral triangle, and the distances between them must all be the same! He adds two more lines to his map.

With the next baseline, he measures the angles between those two points and house 5. This triangle isn't a nice clean right triangle or an equilateral triangle. He has to use his trigonometry skills to figure out the other angle and distances. Fortunately, he knows how to do that. At this point, he could draft a map with the information he has by plotting it on a grid, or he could keep on measuring, adding more detail until he is done.

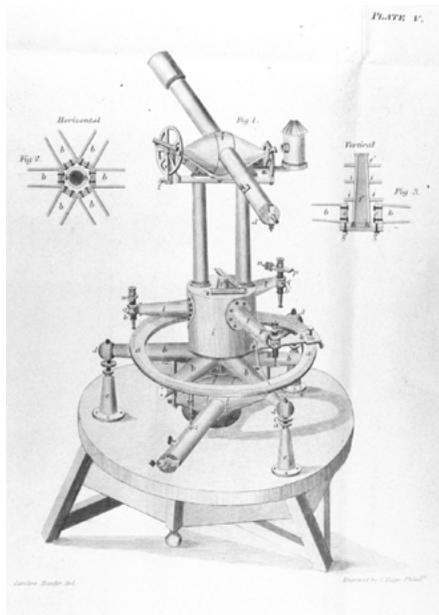
This process of establishing position by using triangles is called **triangulation**. It's very useful because the curve of the earth and the impracticality of using measuring tape over long distances make surveying spaces larger than a room quite tricky. Of course, a strong understanding of trigonometry is helpful as well.

This method can also be used to make elevation maps or to determine the heights of mountains or buildings. Surveyors use a special tool called a **theodolite**. This tool is essentially a telescope mounted on a tripod. It has two built-in protractors: one is like a compass to measure angles along the ground; the other is vertical, like an



Triangulation—step 3

astrolabe, to measure angles up and down. (You can make a simple version of a theodolite with a protractor, a straw, and a level—or you can get one as an app for your mobile phone!)



An old-fashioned theodolite

## *Cartography*

As I've said before, cartography is the art and science of drawing maps. We've talked a lot about the science involved (gathering data, taking measurements, triangulation, etc.), but there's also an art to it. An ideal map is both useful and beautiful. Choosing what to label, the fonts and colors used, the symbols and icons, where to put the key and title, and thinking about how to make things easy to read—all these are part of the art of cartography. In fact, a beautiful map is (in some ways) more useful than an ugly one. Maps should be clear, legible, and attractive if they are to be useful, practical, and helpful.

If nothing else, I hope this lesson has given you an appreciation for how much work goes into each map you look at. Just imagine how many people spent hours (or in some cases, their whole lifetime!) making surveys of places all over the world, collecting information (like place names, latitudes and longitudes, population, photographs and more), and distilling that information into a map for your benefit.



*A navy surveyor using a modern theodolite*

## *New York City Grid*

You could say that modern Manhattan was planned by three men. In the late eighteenth and early nineteenth centuries, there were ongoing disputes because many city property lines had been confused during the Revolutionary War. The city was also growing quickly; and the Common Council, which had been approving construction on an ad hoc basis, wanted a more organized approach to city planning. In 1807 a commission of three members was appointed to lay out a master plan for the growth of New York. They decided that Manhattan should be laid out in a grid pattern, with streets intersecting at right angles and lots laid out in squares or rectangles. The commissioners (1807) chose this plan based on a belief in its order and convenience. They especially emphasized convenience for housing, saying that “straight-sided and right-angled houses are the most cheap to build and the most convenient to live in.”

Other popular city plans at the time included plazas and circles, a design seen in the layout of Washington, D.C. (planned 1791). The commissioners of New York (1807) seem to have felt that these elements were decorative but inconvenient; they indicated that they had decided against “supposed improvements by circles, ovals, and stars.”

Opinions on New York’s grid vary. Some people complain that the grid produces traffic problems, especially since it was designed before the invention of the automobile. On the other hand, it makes Manhattan relatively easy to navigate. The grid has also proven surprisingly flexible in accommodating different design elements. For instance, Central Park was built after the grid system had been chosen, and it still fit into the city layout.



*An 1827 map of Manhattan*

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## Lesson 3.3

# Global Positioning Systems

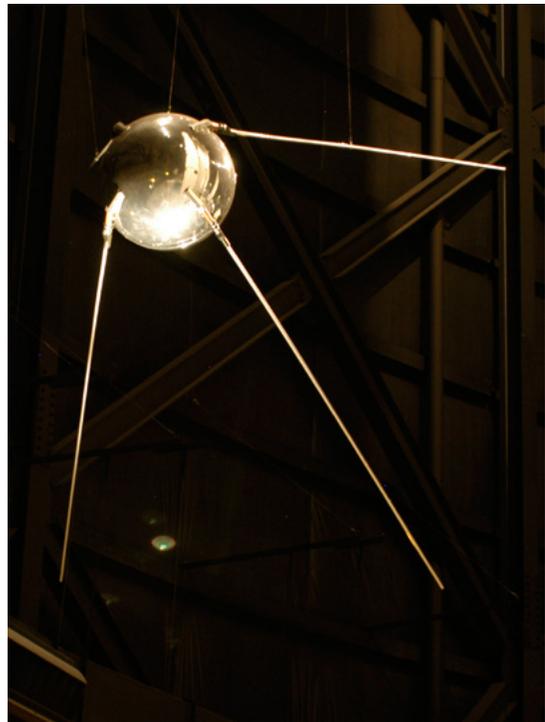
### *Satellites*

In 1957, the Soviet government launched Sputnik, the very first man-made orbital satellite. Its main purpose was to gather information about the earth's atmosphere, but it is most famous for starting the space race during the Cold War. American was stunned by Sputnik. Two American physicists, William Guier and George Weiffenbach, discovered that they could plot the precise location of the satellite by analyzing the radio signals that it sent out (something that even the Soviets didn't realize could be done).

Shortly thereafter, the U.S. government started testing the first of a series of navigational satellites. Originally designed for military use during the Cold War, these satellites (and their replacements) would form the basis of the modern Global Positioning System (GPS). The first modern GPS satellite was launched in 1990. Several generations of satellites have since been launched, and our current system is combination of both modern and older legacy units. Some of the older units are decommissioned—they still orbit and can be used as spares if needed, but they don't actively broadcast a signal.



*GPS satellite (artist's rendition)*



*Sputnik 1*

## Trilateration

Your GPS uses a process called **trilateration** to determine its location based on the messages from the satellites. Trilateration is similar to triangulation, except that it relies on circles and spheres instead of triangles to determine position.

Here's an example: Let's say you are in the middle of the United Kingdom, but you don't know where. A friendly passerby gladly informs you that you're about 312 miles away from Glasgow, Scotland. If you drew a circle with a radius of 312 miles from Glasgow on a map, it would look like this:



312 miles from Glasgow

Unfortunately, that's not terribly helpful. That circle goes through a lot of locations, including Bristol, Oxford, and Cambridge. You've ruled out a lot of locations, but you need to be more precise. Asking another bystander, you find out that you are not in Oxford, which is about 60 miles away. That knowledge lets you add another circle to your map—this one centered on Oxford with a radius of 60 miles:



*60 miles from Oxford*

You're much closer. In fact, you've narrowed it down to two points along the line: Cambridge and Bristol. One more circle and you should know for sure where you are. Another friend informs you that Cardigan, Wales, is 98 miles away, giving you the last clue you need. Adding your final circle reveals this map:



*98 miles from Cardigan*

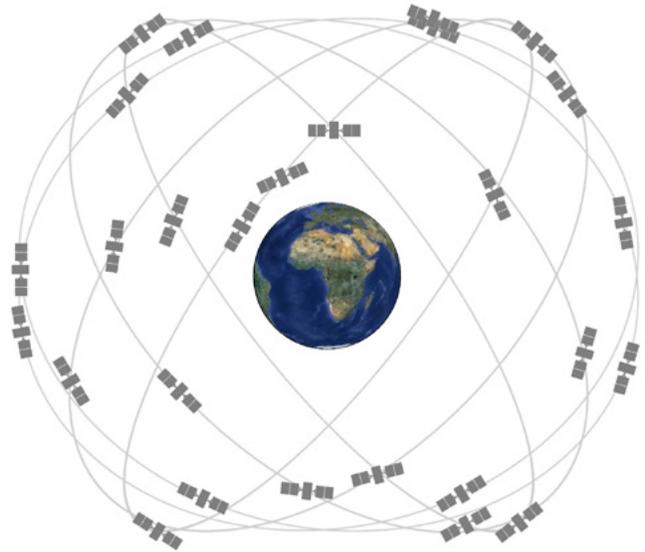
You're in Bristol! It's the only location that fits the distances from those three other cities. That's how trilateration works. There's no measuring angles, just finding intersecting circles.

GPS uses the same principle, but applies it to three-dimensional space (think spheres instead of circles). Instead of cities like Glasgow, Oxford, and Cardigan, the reference points are satellites, which broadcast their position in space. GPS satellites send out a radio signal twice every minute.

It takes 30 seconds to relay three pieces of information:

1. what time it is (the clock)
2. where the satellite is (the ephemeris)
3. where every other satellite is (the almanac)

The satellite signal broadcasts the time at which the signal was sent; your GPS unit compares that to the time at which it was received and calculates how far away the satellite is. Your GPS receives this information from no fewer than 4 satellites at the same time to establish a precise location. Today, there are about 30 satellites forming the GPS constellation. This ensures that between 4 and 12 satellites are visible from any point on earth at all times.



*GPS constellation*

## ***Geocaching***

While GPS technology started out as a purely military endeavor for precision missile strikes and defense (and even though it is still owned and maintained by the U.S. government), the satellites broadcast on civilian channels as well. This signal is used by all kinds of things, including aviation and marine navigation equipment, cellular phones, off-road devices, automotive navigation systems, search and rescue teams, surveyors, and cartographers.

Today, GPS units are used for recreation—not just military applications. In fact, entire pastimes are based on personal GPS units available to anyone. One such activity is called **geocaching**. The basic idea is that one person will hide a treasure chest (called a **cache**) on a piece of public land like a park or bridge. That cache will include a logbook. The cache's owner will put the latitude and longitude coordinates of the cache online and give hints about its whereabouts. Later, other geocachers will visit the website, write down the coordinates, and use their own GPS units to try to find the cache. When they do, they'll write their name and date in the logbook. Some caches include treasure (trinkets, usually) for the hunter to find. Usually, the hunter will take the treasure and leave something else in return for the next person to find. It's a great sport that anybody can play! (For more information, visit [www.Geocaching.com](http://www.Geocaching.com).)

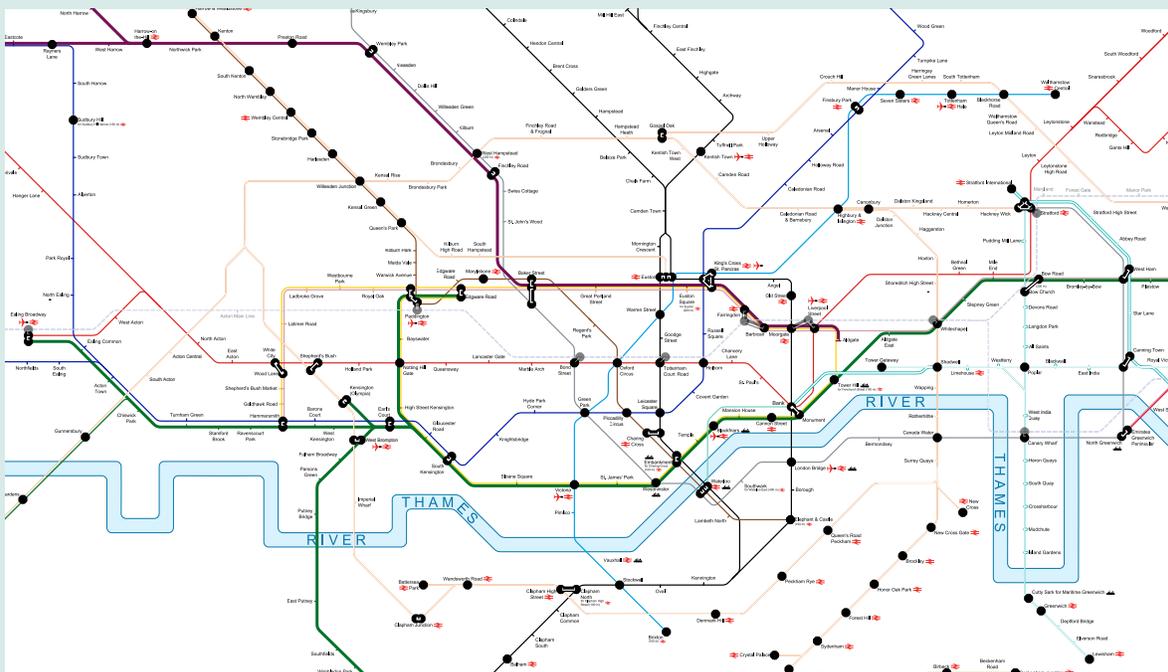
A variation of this activity is called letterboxing. It's very similar, except that it relies on verbal clues and directions instead of GPS coordinates. Visit [www.LetterBoxing.org](http://www.LetterBoxing.org), or [www.AtlasQuest.com](http://www.AtlasQuest.com) for more info.

## The Tube Map

One of the most acclaimed maps in the world is geographically inaccurate and not to scale. Yet people using it frequently rave about how easy it is to follow. This is the London Underground railway map, often called the Tube map since the London subway is nicknamed the Tube.

Early maps of the Tube were much more geographically accurate but much harder to follow. They showed surface roads and features as well as the Underground lines. As Underground authorities kept refining the maps, eventually they had no surface details at all, except for the River Thames. The maps also began to use specific colors for particular lines the subway took. This made it much easier for travelers to navigate the subway system.

Harry Beck, an employee of the Underground system, made the Tube map even easier to follow around 1931. He redesigned it so that it didn't show the exact geographic relationships of stations at all. Rather, a clear diagram showed the direction the lines were heading as you continued along them, the order of the stations along the way, and the places where you could change lines. The public accepted the map immediately when it was released in January 1933, and the current London Tube maps are still based on Beck's design. An unexpected advantage was found during World War II. The British government forbade the release of some kinds of maps for fear the enemy would use them to attack, but the Tube maps were allowed to continue publication because they weren't considered accurate enough to help invaders.



*A portion of a 2012 Tube map*

# Glossary

## A

- absolute bearing: Your bearing when north is used as the reference point for 0°. (Lesson 2.3)
- abyssal plain (deep ocean) floor: The area following the continental rise, at depths of 13,000 to 21,000 feet. (Lesson 4.3)
- accents: Variations in language that affect only pronunciation. (Lesson 13.3)
- active: The state of a volcano that could erupt at any time. (Lesson 6.2)
- aeolian landforms: Landforms formed by wind. (Lesson 5.1)
- aftershock: Generally subject to a consistent rate of decrease in frequency as they become farther away from the main quake. (Lesson 6.3)
- agrarian society: The second stage of societal development. People rely on agriculture—farming, herding, or a combination—to sustain themselves. Agrarian society can include both subsistence agriculture and surplus, the latter of which encourages population growth. (Lesson 10.1)
- agribusiness: The entire process of producing, transporting, processing, distributing, and selling farm products. (Lesson 12.3)
- air mass: A distinct body of air with uniform characteristics across the horizontal layers of the mass. (Lesson 8.2)
- Albers equal area conic projection: Map projection developed by German cartographer Heinrich Christian Albers in 1805. It is especially useful for maps of the United States. (Lesson 2.2)
- alloy: A metal combined with other elements (and is stronger than metal alone). (Lesson 6.1)
- Alpine-Himalayan System: Running east/west, this mountain system goes from the North American Appalachian Mountains, to Europe, the Atlas Mountains, the Alps, and the Zagros Mountains, and finally splits at the Tien Shan and the Himalayas. (Lesson 6.2)
- altitude: Elevation; vertical measurement (height above sea level). (Lesson 5.1)
- amplitude: The amount of waves and vibrations created by an earthquake. (Lesson 6.3)
- animal husbandry: Raising, breeding, and caring for livestock. (Lesson 12.2)
- Antarctic Circle: The polar circle in the south, at 66.5°. (Lesson 2.1)
- Antarctic kingdom: This kingdom includes Antarctica, the temperate and subpolar regions of South America, New Zealand, and many small islands or island chains in the far southern Atlantic and Pacific. (Lesson 9.3)
- aquatic: One of the five major biomes of the world, including all the regions primarily consisting of water. It is subdivided into freshwater and marine regions. (Lesson 9.1)
- aquifer: Permeable underground space that fills or flows with water. Usually made of sand, silt, or rocks that water flows between. (Lesson 7.3)

## ABOUT THE AUTHOR



**TYLER HOGAN** is the head of curriculum development at Bright Ideas Press. He and his wife, Helen, are both homeschool graduates and now homeschooling parents. Tyler is a member of the Association of American Geographers. He has spoken, performed, and taught classes around the world on geography, homeschooling, the arts, and worldview. He also works as the chief operating officer for Grace for Dover, a local mercy ministry. In his spare time, he teaches homeschool co-op classes, reads, and brews an amazing cup of tea. He holds a BA in theatre from Belhaven University and loves the adventure of lifelong learning. Find him online at:

[www.TylerHogan.com](http://www.TylerHogan.com)



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