

GRADE 5 GEOGRAPHY: EXPLORERS, NAVIGATORS AND MISSIONARIES

A year of true stories about the people who found their way across the open ocean and the unmapped lands, from Prince Henry's caravels creeping down the coast of Africa and Vasco da Gama's voyage to India to John Harrison's sea clocks, Mercator's map, Captain Cook's Pacific, the missionaries who mapped Africa and China, and the race to the poles and the top of Everest, each one told honestly and then tried at the kitchen table with a quadrant, a ball of paper and a map notebook.

First edition

"And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;" (Acts 17:26, KJV)

COURSE GUIDE

This course follows the great age of exploration through one school year, and then carries the story on to the ends of the earth. Each unit is built around real people and real moments: Prince Henry of Portugal sending caravels down the coast of Africa, Bartolomeu Dias rounding the Cape of Good Hope in 1488, Vasco da Gama reaching India in 1498, four British warships wrecked on the Isles of Scilly in 1707, the Longitude Act of 1714, the carpenter John Harrison and his sea clocks, Gerardus Mercator's map of 1569, Captain Cook watching the transit of Venus from Tahiti in 1769, William Carey in India, David Livingstone at Victoria Falls, Hudson Taylor in inland China, Mary Slessor in Calabar, Amundsen at the South Pole, Shackleton's *Endurance*, and Hillary and Tenzing on the summit of Everest on May 29, 1953.

Every lesson follows the same path. First comes **the story**: who went, where, when and why. Then **how they found their way**: what problem stood in the way, what tools and skills they used, what went wrong and what they learned. Then **the big idea** underneath, explained for a fifth grader: latitude and longitude, degrees and minutes, dead reckoning, the nautical mile, time and place, map projections, triangulation. Last, the student does it with his or her own hands: a straw-and-protractor quadrant, a noon shadow that gives your own longitude, a projection peeled from a ball, a coastline charted from a toy boat, and a map in the map notebook.

A thread runs through the whole year: **technology overcoming geography**. For thousands of years, the open ocean was a wall. Sailors who lost sight of land could guess their position but not know it, and many ships were lost. The astrolabe and the quadrant let a navigator find his latitude from the sun and the North Star; the chip log and the compass let him reckon his course; John Harrison's chronometer finally solved longitude; and Mercator's projection gave sailors a chart on which a straight line was a steady compass course. Lessons that carry this thread are marked ☼.

The course is written from a Christian view of the world. God made the earth and set the nations upon it: "And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;" (Acts 17:26). Many of the people in this course went out because of the Lord's command, "Go ye into all the world, and preach the gospel to every creature" (Mark 16:15), and some of the best maps of Africa and Asia were drawn by missionaries. The course also tells the truth about real wrongs, such as the slave trade the Portuguese began on the African coast and the cruelty of conquest. Students learn to judge explorers by the standard of truth: to honor courage and skill, and to name wrongdoing plainly.

WHO IT IS FOR

Written for students in grade 5 (about ages 10–11) who read on their own, can multiply and divide, and are learning to measure angles with a protractor. A parent or teacher reads along, helps with the night-sky and outdoor projects, and talks through the harder stories. No earlier geography course is needed. Nothing needs to be bought beyond ordinary

household items: a protractor, a ruler, graph paper, a ball, a watch or phone clock, and a world map or globe.

HOW TO USE THIS COURSE

The weekly rhythm. The year has 32 lessons in 8 units, one lesson a week, plus an optional bonus unit called **Map Lab**. Session 1 (about 45 minutes) is the warm-up, the story, the video and the picture study. Session 2 (about 45 minutes) is the worked examples, the project and the map notebook. In the last week of each unit, add a third session for the unit review and the unit project. Unit 3, on longitude, pairs well with fifth-grade math on degrees and time.

The ★ quarter path and the ⚙ thread. Ten lessons are marked ★. Together they make a one-quarter version of the course for families who want a shorter study or who are combining several subjects; they keep the core skills and the main stories. Lessons marked ⚙ carry the thread of technology overcoming geography: the instruments, clocks and maps that let sailors know where they were.

The map notebook. Use one graph-paper composition book for the whole year. Every lesson ends with something drawn or plotted: a route, a latitude reading, a dead-reckoning course, a time-zone chart, a projection sketch, a coastline or a journey map. Date every page, give it a title, a compass rose and a key, and write one sentence about what the map shows.

Worked examples and practice. Each lesson has two worked examples that show every step, such as finding latitude from the height of the North Star or turning a difference of three hours into 45 degrees of longitude. Then come eight practice questions, with answers for the parent at the end of the lesson. Work the first one or two together; let the student try the rest and check them right away.

Unit reviews and unit projects. Each unit ends with a short review (50 points, 8–12 items) and a unit project that pulls the unit together: a route map to India, a quadrant reading log, a longitude-from-noon report, a projection comparison, a coastline chart, a missionary journey map with letters home, a polar route map or a Columbian Exchange chart. Keep the unit projects in one folder for the year.

Where this course fits. This is the fifth year of the School Launch Geography series, which runs from first maps in kindergarten to high school electives on borders, trade routes and geopolitics. It works well alongside the School Launch Engineering & Physics course, which builds the same habit of taking a machine apart to see how it works, and the Business & Finance course, which tells the spice trade and the sea routes from the merchant's side.

SCOPE AND SEQUENCE

Unit 1: The Portuguese Open the Ocean (1–4)

Prince Henry and the caravels that sailed down Africa; Dias at the Cape of Good Hope (1488); da Gama's sea route to India (1498); and why pepper, cloves and nutmeg were worth so much.

Unit 2: Where Am I? Latitude at Sea (5–8)

The height of the North Star tells your latitude; the astrolabe and the quadrant measure the sun; dead reckoning with the chip log; and the Scilly disaster of 1707, when four warships were lost to a navigation error.

Unit 3: The Longitude Problem (9–12)

Parliament's prize of 1714; John Harrison's clocks from H1 to H4; why each hour of difference is 15 degrees of longitude; and the copy of H4 that sailed with Cook on his second voyage.

Unit 4: Mapping the World (13–16)

Ptolemy's Geography; the Waldseemüller map of 1507 that first named America; Mercator's projection of 1569 and why Greenland looks huge; and the trade-offs of every flat map of a round earth.

Unit 5: Captain Cook and the Pacific (17–20)

The transit of Venus at Tahiti (1769); the careful charts of New Zealand and Australia; how fresh food and sauerkraut fought scurvy; and Cook's death in Hawaii (1779).

Unit 6: Missionaries as Geographers (21–24)

William Carey in India; David Livingstone at Victoria Falls (1855) and the maps he sent home; Hudson Taylor in inland China; and Mary Slessor in the rain forest of Calabar.

Unit 7: The Ends of the Earth (25–28)

Peary and Henson in 1909 and the debate over the North Pole; Amundsen at the South Pole (December 14, 1911); Shackleton's *Endurance*, with every man saved; and Hillary and Tenzing on Everest (May 29, 1953).

Unit 8: Judging Explorers Honestly (29–32)

The courage and skill of the explorers; real wrongs told plainly, from Columbus's governorship to the slave trade and conquest; the Columbian Exchange of plants, animals and disease; and a short essay on what makes a good explorer.

Unit 9: Map Lab (optional bonus) (Optional)

Map games and puzzles: find a ship from latitude and longitude clues, play an explorer trading-card game, draw an old-style map with a compass rose and a cartouche, and find your way in the park.

MATERIALS

- **Map notebook (a graph-paper composition book):** One for the whole year: routes, latitude readings, dead-reckoning courses, time-zone charts, projections and journey

maps.

- **A protractor, a ruler and a drinking straw:** For the straw quadrant in Unit 2 and for measuring angles and courses all year.
- **A world map or atlas, and a globe if you have one:** Any up-to-date atlas works. A free printable outline map is fine for drawing routes.
- **A watch or clock set to the correct time, and a straight stick or pencil for a shadow stick:** For finding local noon and your own longitude in Unit 3.
- **A small ball or an orange, and paper:** For peeling a globe and comparing map projections in Unit 4.
- **String, a compass (the direction-finding kind) and a toy boat or small block:** For triangulation and charting a coastline in Unit 5, and for orienteering in Map Lab.
- **Colored pencils, tracing paper, index cards and tape:** For maps, explorer cards, old-style maps and timelines.
- **Kitchen supplies for small projects:** Small amounts of pepper, cinnamon, cloves and nutmeg for the spice tasting; ice cubes and gloves or mittens for the insulation test; a few foods for the Columbian Exchange chart.
- **Optional: one of the books or resources listed in a unit:** Never required. See the list in each unit.

GRADING

Grades come mostly from the projects and the map notebook, because geography and navigation are learned by measuring, plotting and drawing. A measurement that came out wrong but is honestly recorded and explained earns full credit.

- Projects (effort, careful measuring and the explain-it step): 35%
- Map notebook (dated pages, titles, compass roses, keys and neat plotting): 20%
- Unit reviews: 20%
- Unit projects: 25%

A 90–100, B 80–89, C 70–79, D 60–69. Below 60: redo the project or review with help.

- Grade the process, not just the result. Did the student predict, measure carefully, record honestly, explain the numbers and say what he or she would do differently?
- A map notebook page earns full marks when it has a date, a title, a compass rose, a key, labeled places and one sentence about what the map shows.
- Practice questions are for learning, not for the grade. Check them together and fix mistakes right away.
- Unit reviews may be done orally for a student who writes slowly; the parent writes down the answers.
- The short essay in Lesson 8.4 is graded on whether the student gives real reasons from the stories, names both courage and wrongdoing, and writes in clear sentences.

A NOTE TO PARENTS

You do not need to be a sailor or a mapmaker to teach this course. Read the story aloud together, watch the video, and then be the student's first mate in the project: hold the flashlight, read the watch, write down the numbers. Ask "Where are we?", "How do you know?" and "What could go wrong?" Those three questions are most of what a good navigation teacher does.

The course tells the history of exploration honestly. The explorers were brave and skilled, and some of them also did real wrong: the Portuguese began the Atlantic slave trade on the African coast, and conquest brought cruelty and disease to the Americas. These things are told plainly and at a level suitable for a ten-year-old, without modern slogans. Read Unit 8 ahead of time if you like, and be ready to talk about how the same person can show great courage and still do wrong, and how Scripture judges us all by the same standard.

Some projects take place outdoors at night, at noon or in a park. Go with the student, choose a safe place, and never look at the sun directly or through any instrument. Above all, the course hopes to raise a young person who loves God's world, wants to know it truly, and sees in the missionaries' journeys why so many were willing to go to the ends of the earth.

CONTENTS

Unit 1: The Portuguese Open the Ocean

- 1.1 Henry the Navigator ★
- 1.2 Bartolomeu Dias Rounds the Cape
- 1.3 Vasco da Gama Reaches India ☼
- 1.4 Why Spices Mattered

Unit 2: Where Am I? Latitude at Sea

- 2.1 The North Star and Latitude ★ ☼
- 2.2 The Astrolabe and the Quadrant ☼
- 2.3 Dead Reckoning ☼
- 2.4 Lost at Sea: The Scilly Disaster of 1707

Unit 3: The Longitude Problem

- 3.1 The Longitude Prize ★ ☼
- 3.2 John Harrison's Clocks ★ ☼
- 3.3 Time Tells Place ☼
- 3.4 Cook Tests the Chronometer ☼

Unit 4: Mapping the World

- 4.1 Ptolemy's Geography ★
- 4.2 Waldseemüller Names America
- 4.3 Mercator's Projection
- 4.4 Projections Compared

Unit 5: Captain Cook and the Pacific

- 5.1 The Transit of Venus ★
- 5.2 Mapping New Zealand and Australia
- 5.3 Scurvy and the Ship's Diet
- 5.4 Cook's Death in Hawaii

Unit 6: Missionaries as Geographers

- 6.1 William Carey Goes to India ★
- 6.2 David Livingstone Crosses Africa ★
- 6.3 Hudson Taylor and Inland China
- 6.4 Mary Slessor of Calabar

Unit 7: The Ends of the Earth

- 7.1 Peary and Henson Near the North Pole ★
- 7.2 Amundsen Reaches the South Pole
- 7.3 Shackleton's Endurance
- 7.4 Hillary and Tenzing on Everest

Unit 8: Judging Explorers Honestly

- 8.1 Courage and Skill ★
- 8.2 Real Wrongs
- 8.3 Exchange Across the Ocean
- 8.4 What Makes a Good Explorer?

Unit 9: Bonus: Map Lab (optional)

9.1 Find the Ship

9.2 Explorer Cards

9.3 Make an Old-Style Map

9.4 Orienteering in the Park

★ quarter path · ⚙ technology overcoming geography

THE PORTUGUESE OPEN THE OCEAN

Six hundred years ago, the edge of the European map lay just south of the Canary Islands, at a dangerous point called Cape Bojador. Beyond it, sailors said, no ship could go and come back. In this unit you will watch a small country on the edge of Europe, Portugal, push that edge south, year after year, until its ships had sailed around Africa and across the Indian Ocean to India. You will meet Prince Henry the Navigator, who sent out caravels for forty years; Bartolomeu Dias, whom a storm carried around the Cape of Good Hope in 1488; and Vasco da Gama, who rode the monsoon winds to Calicut in 1498.

You will also ask why they went. The answer smells like a spice cupboard: pepper, cinnamon, cloves and nutmeg, which grew only in a few hot lands near the Equator and cost a fortune in Europe. Along the way you will measure distances with degrees of latitude, learn how sails and winds let ships overcome the ocean, and judge these explorers honestly. Their courage and skill were real. So were their wrongs, above all the slave trade the Portuguese began on the coast of Africa in the 1440s.

God “hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation” (Acts 17:26). In this unit, peoples of Europe, Africa and Asia who had never met by sea came face to face. Watch how they treated one another, and remember that every one of them was made by the same Creator.

BEFORE YOU BEGIN

- Can find the Equator, the continents and the oceans on a globe
- Can multiply a two-digit number by a two-digit number (such as 11×69)
- Can divide money amounts by a whole number (such as $\$4.00 \div 2$)
- Knows the eight compass directions (N, NE, E, SE, S, SW, W, NW)

MASTERY CHECKLIST

- I can tell the stories of Henry the Navigator, Bartolomeu Dias and Vasco da Gama in order, with their key dates (1434, 1488, 1498).
- I can trace the Portuguese route to India on a map and name its main stops.
- I can find north-south distances with latitude, subtracting on the same side of the Equator and adding across it, at about 69 miles per degree.
- I can explain how the caravel, the lateen sail, the volta and the monsoon winds helped sailors overcome the ocean.
- I can explain why spices were so costly in Europe and compute price per ounce and a doubling markup.
- I can judge these explorers honestly, naming their courage and skill and the real wrongs they did.

OPTIONAL BOOKS AND RESOURCES

- **The Cantino Planisphere on Wikimedia Commons**
([https://commons.wikimedia.org/wiki/File:Cantino_planisphere_\(1502\).jpg](https://commons.wikimedia.org/wiki/File:Cantino_planisphere_(1502).jpg)): Free. A large, zoomable image of the 1502 map in the picture study for Lesson 1.3. Zoom in on Africa, the Cape of Good Hope and India.
- **Royal Museums Greenwich** (<https://www.rmg.co.uk/>): Free to browse. The collections of the National Maritime Museum include astrolabes, globes and charts from the age of exploration. A parent can search the collections for “astrolabe” to see the instrument da Gama’s pilots used.

1.1 HENRY THE NAVIGATOR ★

OBJECTIVES

- Tell who Prince Henry of Portugal was and how he sent caravels, year after year, down the coast of Africa in the 1400s.
- Explain why passing Cape Bojador in 1434 mattered and how the caravel's triangle sail helped sailors get home against the wind.
- Use degrees of latitude (about 69 miles each) to find how far south the Portuguese pushed, and name plainly the wrong of the slave trade that began on these voyages.

Warm-up. Lay a long piece of string or yarn on the floor and call it the coast of Africa. Put a toy boat or a bottle cap at the top end. Each time your parent claps, the boat may move one hand-length down the coast, but only if you can say one thing you would need to bring on a ship sailing where no map has ever gone (water, food, a compass, courage...). How far can you get before you run out of ideas? Sailors in Henry's day had to think of all of it.

Video. Coming soon. Henry the Navigator, Sagres and the Portuguese caravel voyages down the African coast: search Drive Thru History, The History Guy, Memoria Press and Smithsonian; Homeschool Pop (Alternate) for a younger overview of the Age of Exploration.

KEY TERMS

caravel

A small, light Portuguese sailing ship of the 1400s, often with triangle (lateen) sails, able to explore shallow coasts and sail closer into the wind.

lateen sail

A triangle-shaped sail hung from a long slanting pole. It lets a ship sail at an angle against the wind better than a square sail.

cape

A point of land that sticks out into the sea. Sailors use capes as landmarks, and some capes are dangerous to pass.

latitude

How far north or south of the Equator a place is, measured in degrees. One degree of latitude is about 69 miles (111 km).

patron

A person who pays for and plans the work of others, such as voyages, without always going along himself.

slave trade

The buying and selling of human beings as property. The Portuguese began carrying captives from West Africa to Europe in the 1440s.

CORE IDEAS

The story. In the year 1415 a young Portuguese prince named Henry, twenty-one years old, sailed with his father, King John I, to capture the city of Ceuta on the north coast of Africa. There he heard of camel caravans that crossed the Sahara with gold and goods from lands no European had ever visited. Henry came home with a question that filled the rest of his life: *what lies down the coast of Africa, past the edge of our maps?* He never became king, and he made almost no long voyages himself. Instead he became a **patron**. From his home near Sagres and the harbor of Lagos, at the far southwestern corner of Portugal, he sent out ship after ship, year after year, for about forty years. English writers centuries later gave him the name we know him by: Henry the Navigator.

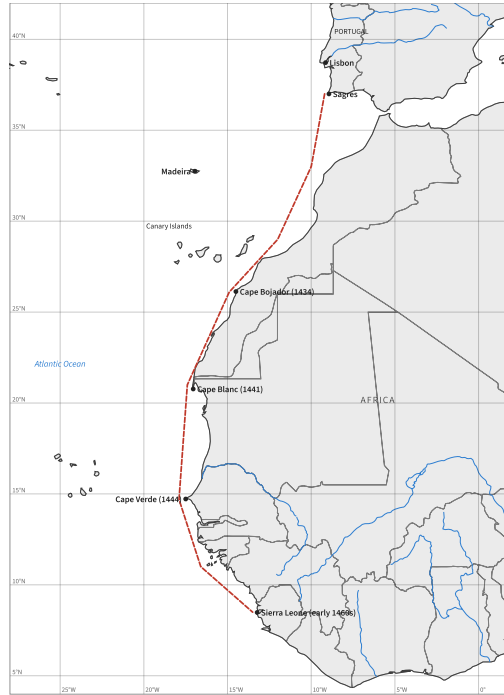
The wall of fear. South of the Canary Islands stood **Cape Bojador**, about 26° north latitude. Sailors said no ship could pass it and come back. The sea there was shallow and rough, strong currents and winds pushed south, and old stories spoke of a “green sea of darkness.” For about twelve years Henry’s captains turned back. In 1433 a squire from Lagos named Gil Eanes turned back too. Henry sent him again, and in 1434 Eanes swung wide out to sea, passed the cape and came home safely. The wall was broken. Within ten years Portuguese ships reached Cape Verde, the westernmost point of Africa, near 15° north.

How it worked. Henry’s captains sailed in **caravels**, ships often only 60 to 80 feet long (about 18 to 24 m) with a crew of about twenty. A caravel floated high enough to creep along unknown shores and up rivers. Most important, many had **lateen sails**, long triangles that let a ship sail at an angle against the wind (see the sail diagram). That mattered, because going south was easy: the wind blew from the northeast at the sailors’ backs. Coming home meant fighting that same wind. Captains learned to swing far out into the Atlantic, northwest toward the Azores, to find westerly winds that would carry them home. The Portuguese called this the *volta do mar*, the “turn of the sea.” Henry also gathered mapmakers, pilots and instrument makers, and each returning captain’s notes went onto new charts. Old stories tell of a famous “school” at Sagres, but historians think there was no school building, only a prince who kept asking questions and paying for answers.

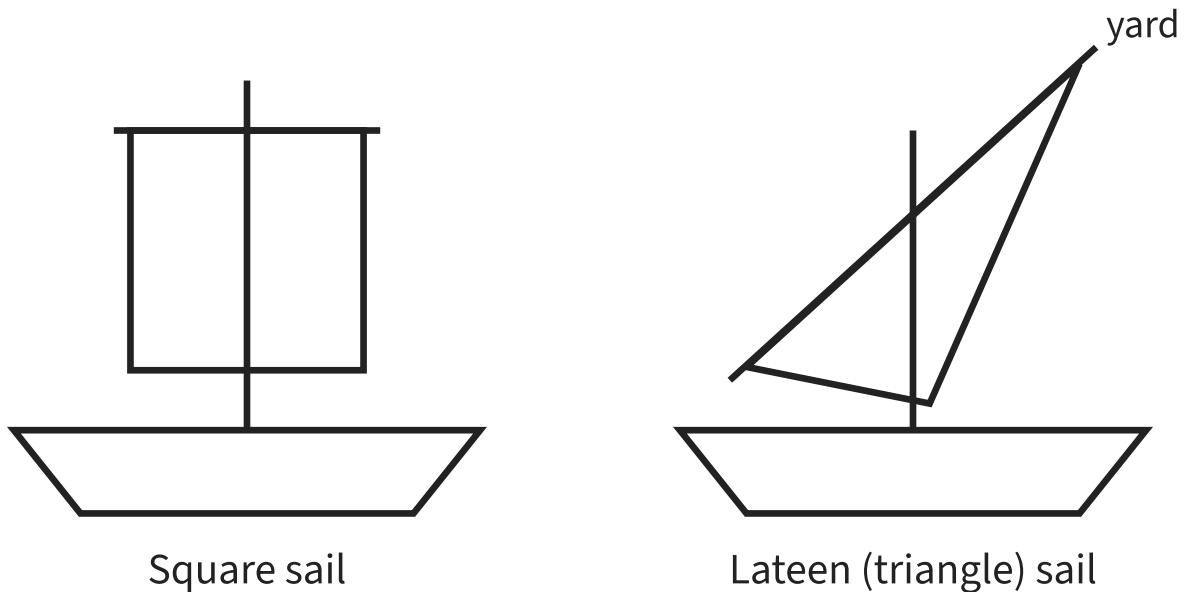
Why he did it. Henry’s chronicler, Gomes Eanes de Zurara, gave several reasons: to learn what lay beyond Bojador, to open trade, to find out how strong the Muslim powers of North Africa were, to find Christian allies, and to bring the Christian faith to new peoples. Henry led the Order of Christ, a knightly order whose red cross was painted on Portuguese sails. Courage, curiosity, money and faith were all mixed together.

A wrong named plainly. In 1441 a Portuguese captain seized African men and brought them home as captives. In August 1444 more than two hundred captives were landed at Lagos and sold. Zurara watched families torn apart and wrote that he wept. Henry, sitting on horseback, took his share, one fifth of the captives. This was the beginning of the Portuguese slave trade on the African coast, which grew over the next centuries into the Atlantic slave trade that carried millions of Africans across the ocean. God’s law had said plainly long before: “he that stealeth a man, and selleth him... shall surely be put to death” (Exodus 21:16). Henry’s courage and patience were real. So was this great wrong.

On the map. Look at the map of Henry's voyages. The coast runs south from Sagres (37°N) to Cape Bojador (26°N), then on to Cape Blanc (21°N) and Cape Verde (15°N), and by the early 1460s, just after Henry's death in 1460, to the coast of Sierra Leone (8°N). Every degree of latitude is about 69 miles. Count the degrees and you can measure how far the Portuguese pushed the edge of the known world.



The coast Henry's caravels explored, 1420s-1460. Each grid line is 5 degrees.



A square sail is best with the wind behind. A lateen (triangle) sail can sail closer into the wind.

PICTURE STUDY



The Panels of Saint Vincent, Attributed to Nuno Gonçalves, about 1470–1480 · Oil and tempera on six oak panels · National Museum of Ancient Art (Museu Nacional de Arte Antiga), Lisbon

These six panels were painted in Portugal not long after Henry's caravels had crept down the coast of Africa. They show about sixty people of Portugal gathered around Saint Vincent, the patron saint of Lisbon: princes and knights, monks, fishermen with their nets, and churchmen. They were rediscovered in a Lisbon monastery in the 1880s and cleaned in the early 1900s.

A man in a wide, round black hat near the center has long been called Prince Henry the Navigator. Scholars still debate whether it is really him, but it is the face most often printed in books about Henry. As you look, remember that we are not certain, and enjoy the faces of the ordinary people who sailed and fished in his day.

Look closely

- Find the man in the large round black hat. What do his face and clothes tell you about him?
- Find the fishermen and their nets. Why would a seafaring country want fishermen in a painting like this?
- Count how many different kinds of people you can find: kings, knights, monks, sailors.
- Look at the colors of the clothes. Which colors does the painter use most?

Talk about it

1. Why do you think a painter would put sailors and fishermen beside princes and knights?
2. Historians are not sure the man in the black hat is Henry. Why is it important to say so honestly?
3. If you painted the people of your own town, whom would you include?

Safety first. Keep the electric fan well away from the water and plugged in on the far side of the room from the tub. An adult should handle the craft knife.

PROJECT: SQUARE SAIL OR TRIANGLE SAIL? A CARAVEL TEST

Henry's sailors needed ships that could get home against the wind. You will build two small boats, one with a square sail and one with a lateen (triangle) sail, and test them with a fan in a tub of water.

You will need

- Two pieces of foam tray, a cork board or two small plastic food tubs for hulls
- Two bamboo skewers or straws for masts, and a third skewer for the lateen's slanting pole
- Paper or a cut plastic bag for sails; tape; modeling clay to hold the masts
- A bathtub or large plastic tub of water, an electric fan, a ruler and a notebook

Steps

1. Cut two hulls about 6 inches (15 cm) long with a pointed front. Press a lump of clay into the middle of each and stand a mast in it.
2. For the square sail, tape a 3-inch paper square across the mast. For the lateen sail, tape a skewer slanting across the mast and hang a paper triangle from it, so the long edge of the triangle runs along the slanting pole.
3. Set the fan at one end of the tub. Test 1: point each boat straight away from the fan (wind behind). Which goes faster?
4. Test 2: point each boat across the wind, at a right angle to the fan. Turn the sail to catch the wind. Which one moves forward instead of only sliding sideways?
5. Test 3: try to point each boat a little toward the fan. Can either one make any headway?
6. Record each test in a chart with three columns: test, square sail, lateen sail.
7. Write two sentences: Which sail would you choose for going south down Africa with the wind behind you? Which for coming home against it?

Tips

- A real ship has a keel under the water that keeps it from sliding sideways. Press a strip of cardboard into the clay under each hull as a keel and see what changes.
- Many later Portuguese ships carried both kinds of sails, square ones for running before the wind and a lateen at the back for steering closer to it.

Check your work

- I built and tested two sail shapes in the same wind.
- I recorded my results in a chart.
- I can explain why a lateen sail helped Henry's caravels come home.

MAP NOTEBOOK

1. Trace the west coast of Africa from Portugal to Sierra Leone. Mark Sagres, Madeira, the Canary Islands, Cape Bojador (1434), Cape Blanc and Cape Verde, with the year each was reached where you know it.
2. Draw a caravel with lateen sails and the red cross of the Order of Christ. Label the hull, the mast, the slanting pole (yard) and the sail.
3. Make a two-column chart titled "Henry the Navigator": on one side, things he did well; on the other, wrongs done under his name.

From history. In Lisbon, beside the Tagus River, stands the Monument to the Discoveries (Padrão dos Descobrimentos), finished in stone in 1960 for the 500th anniversary of Henry's death. It is shaped like the prow of a ship. Henry stands at the front holding a small caravel, and behind him come carved figures of captains, mapmakers, missionaries and poets, among them Bartolomeu Dias and Vasco da Gama, whom you will meet in the next two lessons.

WORKED EXAMPLES

Example 1. Sagres is at about 37° north latitude. Cape Bojador is at about 26° north. About how far south of Sagres is Cape Bojador, in miles and in kilometers?

(Use the map or drawing "Use the grid lines to check the latitudes of Sagres and Cape Bojador." shown earlier in this lesson.)

1. Both places are north of the Equator, so subtract: $37^\circ - 26^\circ = 11^\circ$.
2. Each degree of latitude is about 69 miles: $11 \times 69 = 759$ miles.
3. In kilometers, each degree is about 111 km: $11 \times 111 = 1,221$ km.

Answer: About 760 miles (about 1,220 km) due south. The ships sailed farther than that, because they followed the curving coast.

Example 2. Cape Verde is at about 15°N. The coast of Sierra Leone, reached in the early 1460s, is at about 8°N. In which compass direction does the coast run from Cape Verde to Sierra Leone, and about how many miles south is Sierra Leone?

(Use the map or drawing “South of Cape Verde the coast of Africa begins to bend toward the southeast.” shown earlier in this lesson.)

1. On the map, Sierra Leone is below (south of) Cape Verde and to the right (east) of it, so the coast runs toward the southeast.
2. Subtract the latitudes: $15^{\circ} - 8^{\circ} = 7^{\circ}$.
3. Multiply: $7 \times 69 = 483$ miles ($7 \times 111 = 777$ km).

Answer: Southeast; Sierra Leone is about 480 miles (about 780 km) farther south.

PRACTICE

1. **EASY** In what year did Gil Eanes sail past Cape Bojador and return safely?
2. **EASY** Why did Henry the Navigator get his name, even though he made almost no long voyages himself?
3. **MEDIUM** The island of Madeira is at about 33°N. Sagres is at about 37°N. About how many miles apart are they north to south?
4. **MEDIUM** Cape Blanc is at about 21°N and Cape Verde at about 15°N. About how far is it north to south between them, in miles and kilometers?
5. **MEDIUM** Look at the map of Henry’s voyages. Name the place marked on the map that is farthest south, and the island group that lies just off the coast near Cape Bojador.
(Use the map or drawing “Henry’s coast, 1420s-1460.” shown earlier in this lesson.)
6. **HARD** Henry was born in 1394 and died in 1460. He was at the capture of Ceuta in 1415. How old was he when Ceuta was taken, how many years later did Gil Eanes pass Cape Bojador, and how old was Henry when he died?
7. **HARD** Going south along Africa was easy, but coming home was hard. Explain why, and tell how Portuguese captains solved the problem.
8. **CHALLENGE** Write three or four sentences judging Henry honestly. Name one thing he did well and one real wrong done under his rule.

COMMON MISTAKES

- Thinking Henry sailed the voyages himself. He planned and paid for them; captains such as Gil Eanes did the sailing.
- Believing there was a famous school building at Sagres. That is an old story; historians think Henry gathered experts around him but had no school.
- Forgetting that latitude is measured from the Equator. A place at 26°N is south of a place at 37°N, because it is closer to the Equator.

Make it a game • Past the Cape. Lay a strip of masking tape down the floor as the coast of Africa and stick on paper labels: Sagres, Madeira, Canaries, Cape Bojador, Cape Blanc, Cape Verde, Sierra Leone. Each player has a bottle-cap caravel at Sagres. To move one stop south, answer a question from the lesson (a parent can read them from the practice list). Cape Bojador is the wall of fear: to pass it you must answer two questions in a row. The first caravel to reach Sierra Leone wins, but it must still sail home by naming the volta do mar.

Scripture. “It is the glory of God to conceal a thing: but the honour of kings is to search out a matter.” (Proverbs 25:2, KJV)

God hid many wonders in His world, and searching them out is an honorable work. Henry spent his life searching out the coast of Africa. Yet searching out the world never excuses harming the people who live in it.

Practice answers

1. 1434.
2. He was the patron of the voyages: he planned and paid for them, gathered mapmakers and pilots, and sent ship after ship down the coast of Africa for about forty years. The name was given to him by later English writers.
3. $37 - 33 = 4^\circ$; $4 \times 69 = 276$ miles (about 444 km).
4. $21 - 15 = 6^\circ$; $6 \times 69 = 414$ miles; $6 \times 111 = 666$ km.
5. Sierra Leone is farthest south. The Canary Islands lie just off the coast, north of Cape Bojador.
6. $1415 - 1394 = 21$ years old at Ceuta. $1434 - 1415 = 19$ years later. $1460 - 1394 = 66$ years old when he died.
7. The wind along that coast blows mostly from the northeast, so it pushed ships south but blew against them going north. Captains used lateen sails to sail at an angle to the wind and made the volta do mar, a wide swing northwest out into the Atlantic toward the Azores, where westerly winds carried them home to Portugal.
8. Sample: Henry showed great patience and courage in sending ships, year after year, past places sailors feared, and his captains made the first good maps of Africa’s west coast. He gathered skilled people and kept asking questions until they were answered. But in 1444 he took his share of African captives sold at Lagos, and the slave trade that began on his voyages grew into a terrible evil. Both things are true, and an honest history tells both.

1.2 BARTOLOMEU DIAS ROUNDS THE CAPE

OBJECTIVES

- Tell the story of Bartolomeu Dias's voyage of 1487–1488 and how a storm carried him around the southern tip of Africa.
- Locate the Cape of Good Hope and Cape Agulhas on a map and explain why rounding them proved a sea road to India was possible.
- Find distances north and south across the Equator by adding degrees of latitude.

Warm-up. Put a globe or a world map on the table. With your finger, start at Portugal and trace the coast of Africa south. Every time the coast turns, say which direction it is turning. Where does the coast stop going south and begin to go north and east? Put a sticky note there. That is the corner Bartolomeu Dias spent his life trying to find.

Watch. *Bartolomeu Dias / 3 Minute History* (Innovative History, 3:26).

<https://www.youtube.com/watch?v=aeYyLA5rKFc>

After the story: watch this three-minute history of Dias's 1487–1488 voyage, and trace on your map how the storm carried him past the tip of Africa before he saw land.

Note: The narrator opens with a joke that Dias looks like a coffee-shop hipster. Transcript checked.

KEY TERMS

Cape of Good Hope

A rocky headland near the southwestern tip of Africa, at about 34° south latitude, first passed by Bartolomeu Dias in 1488.

Cape Agulhas

The true southernmost point of Africa, about 90 miles (150 km) east-southeast of the Cape of Good Hope.

padrão

A stone pillar topped with a cross and carved with the royal arms, set up by Portuguese captains to mark the farthest point they reached.

Equator

The imaginary line around the middle of the earth at 0° latitude. Places south of it have south latitudes.

headland

A high point of land that sticks out into the sea, like a cape.

CORE IDEAS

The story. Henry the Navigator died in 1460, but Portugal kept sailing south. In the 1480s King John II sent Diogo Cão down the coast past the mouth of the Congo River, about 6°

south of the Equator, and as far as Cape Cross, near 22°S. Africa simply kept going. Was there an end to it? In August 1487 the king sent a knight of his household, Bartolomeu Dias, to find out. Dias sailed from Lisbon with two caravels and a supply ship. He left the supply ship with some of the men on the coast of what is now Angola and pushed on south with the two caravels.

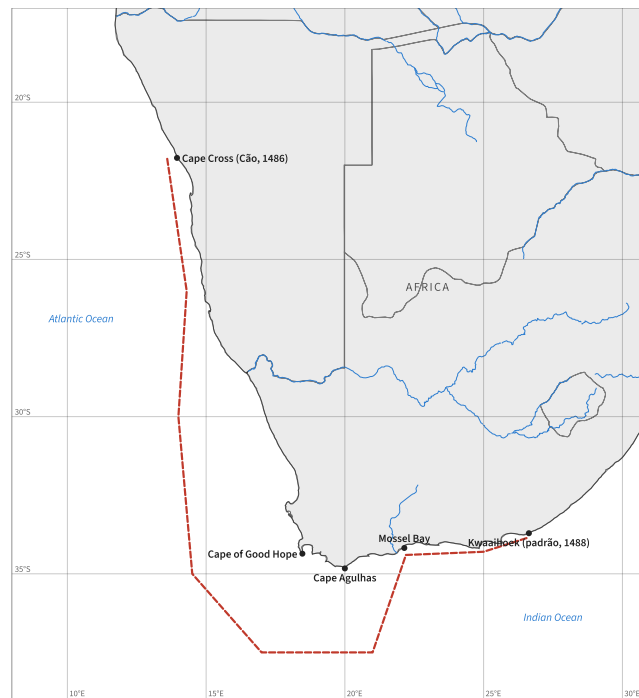
Blown off the map. Somewhere past the coast of today's Namibia a great storm struck. For many days the caravels ran south before the wind with only a little sail up, far out of sight of land, into cold waters no European had ever sailed. When the storm eased, Dias turned east to find the coast again. He sailed and sailed and found no land. Then he turned north, and in early February 1488 he sighted mountains and came ashore in a bay of green grass and cattle, now called Mossel Bay. The coast there ran east, not north and south. Without seeing it, Dias had sailed around the bottom of Africa.

The crew says no. At Mossel Bay the Portuguese met Khoikhoi herders. They did not share a language, and a quarrel at a watering place ended with a herder killed by a crossbow bolt. Dias sailed on east and north along the coast. Now the coast bent clearly to the northeast, toward India. But the men were worn out, food was low and the supply ship was far behind. His officers and crew asked to turn back. Dias called a council and they agreed: they would go only a few days more. In March 1488 he set up a stone **padrão** at a point called Kwaaihoek, near the mouth of the Bushmans River, sailed on a little way to the Great Fish River, and turned for home. It is said he left the pillar as if he were leaving a son behind.

The cape at last. On the way home, sailing west along the coast, Dias at last saw the great headland the storm had hidden. According to the Portuguese historian João de Barros, Dias called it the Cape of Storms. King John II gave it a better name, the **Cape of Good Hope**, because now there was good hope of reaching India by sea. Dias reached Lisbon in December 1488, after about sixteen months away. He had sailed farther south than any European captain before him and proved that the Atlantic and Indian Oceans were joined.

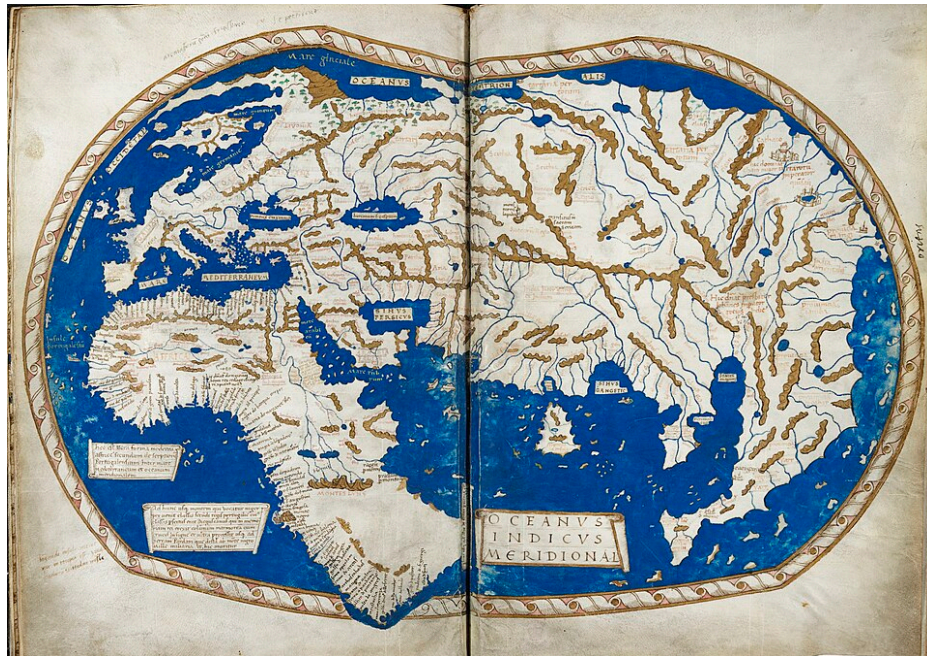
On the map. Look at the map of southern Africa. The Cape of Good Hope is at about 34°S. Many people think it is Africa's southern tip, but **Cape Agulhas**, about 90 miles (150 km) to the east-southeast, reaches a little farther south. Lisbon is at about 39°N. To find the distance between places on opposite sides of the Equator, you *add* the degrees: $39 + 34 = 73$ degrees, about 5,000 miles (8,100 km) in a straight line north to south. Dias sailed much farther than that along the curving coast and out into the storm.

The big idea. Dias did not reach India, and he received little reward. But his voyage changed the map of the world. Before 1488, some old maps drawn after Ptolemy showed the Indian Ocean as a closed lake with land all around it. Dias showed that a ship could sail from Lisbon into the Indian Ocean. In the same years, King John sent a traveler named Pêro da Covilhã overland through Egypt and Arabia to India and East Africa to learn about the spice trade. The sea road and the land reports together prepared the way for Vasco da Gama.



Dias's voyage around the Cape, 1488 (route approximate). Each grid line is 5 degrees.

PICTURE STUDY



World Map of Henricus Martellus, Henricus Martellus Germanus, about 1490 · Ink and paint on parchment (vellum), in a manuscript book of maps · British Library, London

Henricus Martellus was a German mapmaker working in Florence, Italy. A few years after Dias came home, he drew this world map using the old maps of Ptolemy for most of the world, but with new news from Portugal for Africa. The coast of Africa is labeled with Portuguese names, and the tip of Africa is drawn with a sea passing around it, just as Dias had found.

Look closely at the bottom. Martellus made Africa reach so far south that its tip pokes right through the border of his map, as if the new knowledge would not fit inside the old frame.

Look closely

- Find the southern tip of Africa. What happens where it meets the border of the map?
- Find the Indian Ocean. Is it drawn open to the Atlantic, or closed in like a lake?
- Compare the shape of Africa here with Africa on a modern globe. What is too long or too short?
- Look for tiny names along the African coast. Why would a mapmaker crowd them in so closely?

Talk about it

1. How could a mapmaker in Florence know about a voyage from Lisbon only a year or two before?
2. Why do you think Martellus let Africa break through the border instead of redrawing the whole map?
3. What parts of this map were still guesses?

PROJECT: SALT-DOUGH CAPE OF GOOD HOPE WITH PADRÕES

You will build a relief map of the southern end of Africa, from Cape Cross to the Great Fish River, and plant small *padrões* where Diogo Cão and Bartolomeu Dias set theirs. Then you will sail Dias's storm route around it with a toy boat.

You will need

- Salt dough: 2 cups flour, 1 cup salt, about 3/4 cup water
- A piece of stiff cardboard about 12 by 12 inches (30 by 30 cm)
- A printed or traced outline of southern Africa (use the lesson map), pencil, paints (blue, green, brown)
- Toothpicks and small paper flags or crosses for *padrões*; a bottle cap or small toy boat; yarn

Steps

1. Trace the outline of southern Africa onto the cardboard. Mark the 20°S, 25°S, 30°S and 35°S latitude lines along the side.
2. Mix the salt dough and press it inside the outline about half an inch (1 cm) thick. Build up the mountains just behind the coast around the Cape and along the south coast a little higher.
3. Press a thumbprint for Mossel Bay and pinch out the points of the Cape of Good Hope and Cape Agulhas, with Cape Agulhas reaching a little farther south.
4. Let it dry (a day or two, or bake at a low heat with an adult's help), then paint the land green and brown and the sea blue.

5. Make padrões from toothpicks with tiny paper crosses. Plant one at Cape Cross (Diogo Cão, 1486) and one at Kwaaihoek (Dias, 1488). Label Mossel Bay, the Cape of Good Hope and Cape Agulhas.
6. Lay yarn to show Dias's route: down the coast, then far south out to sea in the storm, east with no land in sight, north to Mossel Bay, east to Kwaaihoek, and back west past the Cape.
7. Sail your bottle-cap boat along the yarn and tell the story aloud to someone at home.

Tips

- Salt dough cracks if it dries too fast. Cover it loosely with a towel for the first few hours.
- Notice how the yarn shows Dias going around the Cape without seeing it the first time.

Check your work

- My map shows the Cape of Good Hope and Cape Agulhas in the right places, with Agulhas farther south.
- My padrões are at Cape Cross and Kwaaihoek.
- I can tell Dias's story using my map.

MAP NOTEBOOK

1. Draw a padrão: a stone pillar with a cube on top carved with the Portuguese arms and a cross. Under it write Kwaaihoek, March 1488.
2. Draw the southern tip of Africa and label the Atlantic Ocean, the Indian Ocean, the Cape of Good Hope, Cape Agulhas and Mossel Bay.
3. Write the two names of the cape, the Cape of Storms and the Cape of Good Hope, and a sentence about why each name fits.

From history. Dias never sailed to India himself, but he helped prepare the ships for Vasco da Gama's voyage in 1497. In 1500 he sailed as a captain in the great fleet of Pedro Álvares Cabral, which touched the coast of Brazil on its way to India. In May 1500, near the very cape he had found, a storm sank several ships of the fleet, and Bartolomeu Dias was lost with his ship.

WORKED EXAMPLES

Example 1. Lisbon is at about 39°N . The Cape of Good Hope is at about 34°S . About how far apart are they, measured straight north to south?

1. The two places are on opposite sides of the Equator, so add: $39^{\circ} + 34^{\circ} = 73^{\circ}$.
2. Each degree of latitude is about 69 miles: $73 \times 69 = 5,037$ miles.
3. In kilometers: $73 \times 111 = 8,103$ km.

Answer: About 5,000 miles (about 8,100 km). Dias sailed much farther than this along the curving coast.

Example 2. Diogo Cão set up his last padrão at Cape Cross, near 22°S , in 1486. Dias rounded the Cape of Good Hope, near 34°S . How many miles farther south did Dias go than Cão?

(Use the map or drawing “Count the degrees between Cape Cross and the Cape of Good Hope.” shown earlier in this lesson.)

1. Both places are south of the Equator, so subtract: $34^{\circ} - 22^{\circ} = 12^{\circ}$.
2. Multiply by 69 miles per degree: $12 \times 69 = 828$ miles.
3. In kilometers: $12 \times 111 = 1,332$ km.

Answer: About 830 miles (about 1,330 km) farther south.

PRACTICE

1. **EASY** What did Dias call the cape, according to the old story, and what name did King John II give it instead?
2. **EASY** Is the Cape of Good Hope the southernmost point of Africa? If not, what is?
3. **MEDIUM** The mouth of the Congo River, which Diogo Cão reached in 1482, is at about 6°S . The Cape of Good Hope is at about 34°S . How far apart are they north to south, in miles and kilometers?
4. **MEDIUM** Dias left Lisbon in August 1487 and returned in December 1488. About how many months was he away?
5. **MEDIUM** Sagres is at about 37°N . About how far is it from Sagres straight south to the Equator?
6. **HARD** Look at the map. After the storm, Dias sailed east and found no land, then turned north and reached Mossel Bay. Which way does the coast run east of Mossel Bay, and why did that tell Dias he had rounded Africa?

(Use the map or drawing “Follow the coastline from Cape Cross to Kwaaihoek.” shown earlier in this lesson.)

7. **HARD** Give two reasons Dias’s crew wanted to turn back at Kwaaihoek.

8. **CHALLENGE** Dias never reached India. Write three sentences explaining why his voyage still mattered so much.

COMMON MISTAKES

- Calling the Cape of Good Hope the southern tip of Africa. Cape Agulhas reaches farther south.
- Subtracting latitudes when the two places are on opposite sides of the Equator. If one is north and one is south, add the degrees.
- Thinking Dias saw the cape on the way out. The storm carried him past it out of sight of land; he saw it on the way home.

Make it a game • Add or Subtract?. A parent calls out two places and their latitudes, such as “Lisbon 39 north, Cape of Good Hope 34 south” or “Cape Cross 22 south, Mossel Bay 34 south.” The first player to shout “Add!” or “Subtract!” correctly scores a point, and a bonus point for giving the number of degrees. Use places from this lesson and the last one. Play to ten points.

Scripture. “He maketh the storm a calm, so that the waves thereof are still.” (Psalm 107:29, KJV)

The storm that drove Dias out of sight of land is the very thing that carried him around Africa. Sailors in every age have learned that God rules the wind and the waves, and that He can bring good out of a frightening storm.

Practice answers

1. Dias called it the Cape of Storms. King John II renamed it the Cape of Good Hope.
2. No. Cape Agulhas, about 90 miles (150 km) to the east-southeast, is the southernmost point.
3. $34 - 6 = 28^\circ$; $28 \times 69 = 1,932$ miles; $28 \times 111 = 3,108$ km.
4. August 1487 to August 1488 is 12 months; August to December is 4 more: about 16 months.
5. $37 \times 69 = 2,553$ miles ($37 \times 111 = 4,107$ km).
6. East of Mossel Bay the coast runs east and then northeast. All the way down the west side of Africa the coast had run south; a coast running east and then northeast meant he had passed the bottom of the continent and was heading up its other side, toward India.
7. Any two: they were worn out after months at sea and the storm; food was running low; the supply ship with extra food was far behind on the coast; they did not know how much farther India was.
8. Sample: Dias proved that Africa has an end and that a ship can sail from the Atlantic into the Indian Ocean. That showed a sea road to India was possible, which is why the king named the cape Good Hope. Ten years later Vasco da Gama followed his route to India, in ships Dias helped prepare.

1.3 VASCO DA GAMA REACHES INDIA

OBJECTIVES

- Trace Vasco da Gama's route of 1497–1498 from Lisbon around Africa to Calicut, naming the main stops in order.
- Explain how ships, sails, the wide swing through the South Atlantic and the monsoon winds let the Portuguese overcome the distance to India.
- Compute speeds and travel times from real dates and distances, and judge da Gama honestly, naming both his skill and his cruelty.

Warm-up. Set a fan on low and point it across the table. Hold a sheet of paper in front of it at different angles. When does the wind push the paper hardest? Now turn the fan to face the other way. Sailors to India had a wind like this fan that turned around twice a year. If you had to cross the sea and come back, when would you leave, and when would you come home?

Watch. *8th July 1497: Vasco da Gama sets sail from Portugal on the first known voyage to India from Europe* (HistoryPod, 2:26). <https://www.youtube.com/watch?v=2sgmkRoXe4w>

After the story: watch this short overview of da Gama's 1497 voyage from Lisbon around the Cape of Good Hope to Calicut, and trace the route on your map as it goes.

Note: Captions were not available to check; preview it first. The description says the meetings with local rulers in Mozambique and Mombasa were tense or hostile. The video uses the modern name Kozhikode for Calicut and says the crew was about 170 men.

KEY TERMS

monsoon

A wind over the Indian Ocean that changes direction with the seasons: from the southwest in summer and from the northeast in winter.

volta

Portuguese for “turn.” A wide swing out into the open ocean to find helpful winds instead of hugging a coast against the wind.

pilot

A sailor who knows a particular sea or coast and guides a ship through it.

Calicut

A rich trading city on the Malabar coast of southwest India, at about 11° north, now called Kozhikode. Da Gama arrived there in May 1498.

scurvy

A sickness caused by going too long without fresh fruit and vegetables (vitamin C). It killed many sailors on long voyages.

CORE IDEAS

The story. On July 8, 1497, four ships sailed from the beach at Belém, just outside Lisbon: the *São Gabriel*, the *São Rafael*, the small *Berrio* and a supply ship. Their captain-major was Vasco da Gama, a hard, determined nobleman sent by King Manuel I. Bartolomeu Dias had helped prepare the ships and sailed with the fleet as far as West Africa. The goal was the one Henry had dreamed of and Dias had made possible: to reach India by sea.

How it worked. Instead of creeping down the African coast against contrary winds and currents, da Gama made a great **volta**. After leaving the Cape Verde Islands on August 3, he swung far out into the South Atlantic in a huge curve and did not see land again until November 4. That was 93 days out of sight of land, by far the longest such voyage any European crew had made. His pilots could find their latitude by measuring the height of the sun with an astrolabe; at St. Helena Bay, north of the Cape, they went ashore to measure it on steady ground. Then they rounded the Cape of Good Hope in late November and sailed up the east coast of Africa, a coast of busy trading towns linked to Arabia and India: Mozambique, Mombasa and Malindi. At Malindi the ruler gave da Gama an experienced pilot who knew the way across the Indian Ocean.

Technology overcoming geography. The Indian Ocean has a wonderful pattern that God set in its winds. In summer the **monsoon** blows from the southwest toward India; in winter it blows from the northeast, back toward Africa and Arabia (see the monsoon diagram). Indian, Arab and African sailors had used it for centuries. Da Gama left Malindi on April 24, 1498, as the southwest winds were rising, and reached the coast near Calicut on May 20, crossing about 2,600 miles (4,200 km) of open sea in less than a month. Sturdy ships, a mix of square and lateen sails, the astrolabe, the knowledge of a local pilot and the seasonal wind together overcame a distance that had kept Europe and India apart by sea for all of history.

In Calicut. When the first Portuguese man went ashore, he met two merchants from Tunis in North Africa who could speak Spanish. They asked what had brought the Portuguese so far, and he answered that they had come “to seek Christians and spices.” The ruler of Calicut, called the Zamorin, received da Gama, but his officials laughed at the gifts the Portuguese offered: striped cloth, hats, coral, basins, sugar, oil and honey. Calicut was rich, and these were poor gifts. The Portuguese even took a Hindu temple for a Christian church. After hard bargaining, da Gama loaded pepper and other spices and left at the end of August.

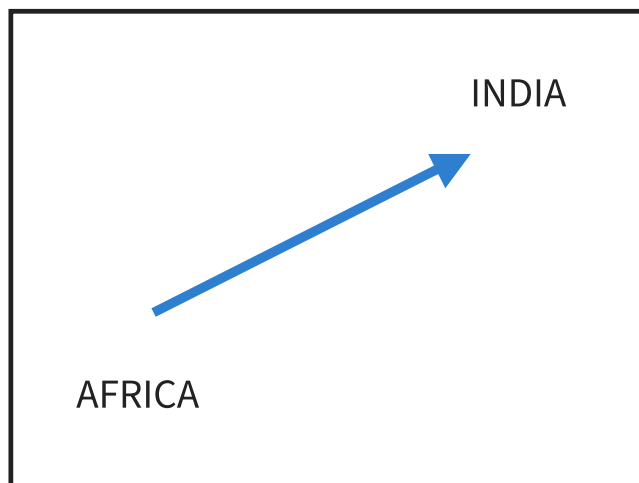
The cost. He started home before the winter wind had turned, and the crossing back to Africa took nearly three months. Scurvy struck; men’s gums swelled and many died. There were too few sailors left to work all the ships, so the *São Rafael* was burned. Da Gama reached Lisbon in the summer of 1499, and fewer than half of his men came home. Still, the spices sold for many times the cost of the voyage, and Portugal had found the sea road to India. Da Gama’s later voyage of 1502 shows his darker side: off the coast of India his fleet captured a ship carrying Muslim pilgrims home from Mecca, took its goods, and set it on fire with hundreds of men, women and children aboard. He also bombarded Calicut. His skill and courage were great; so was his cruelty.

On the map. Follow the route on the map: Lisbon (39°N) to the Cape Verde Islands (15°N), the great curve through the South Atlantic, St. Helena Bay, the Cape of Good Hope (34°S), Mozambique, Mombasa, Malindi (3°S), and across the Arabian Sea to Calicut (11°N). The whole voyage, there and back, was more than 20,000 miles.



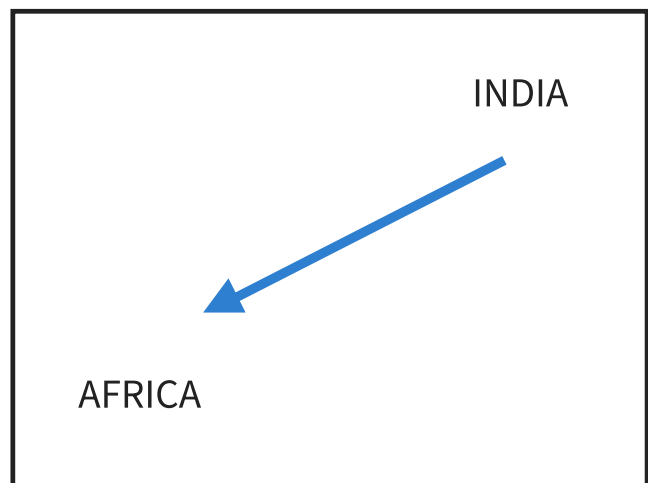
Vasco da Gama's route to India, 1497-1498 (approximate). Grid lines every 10 degrees.

Summer (June–Sept.)



Southwest wind: toward India

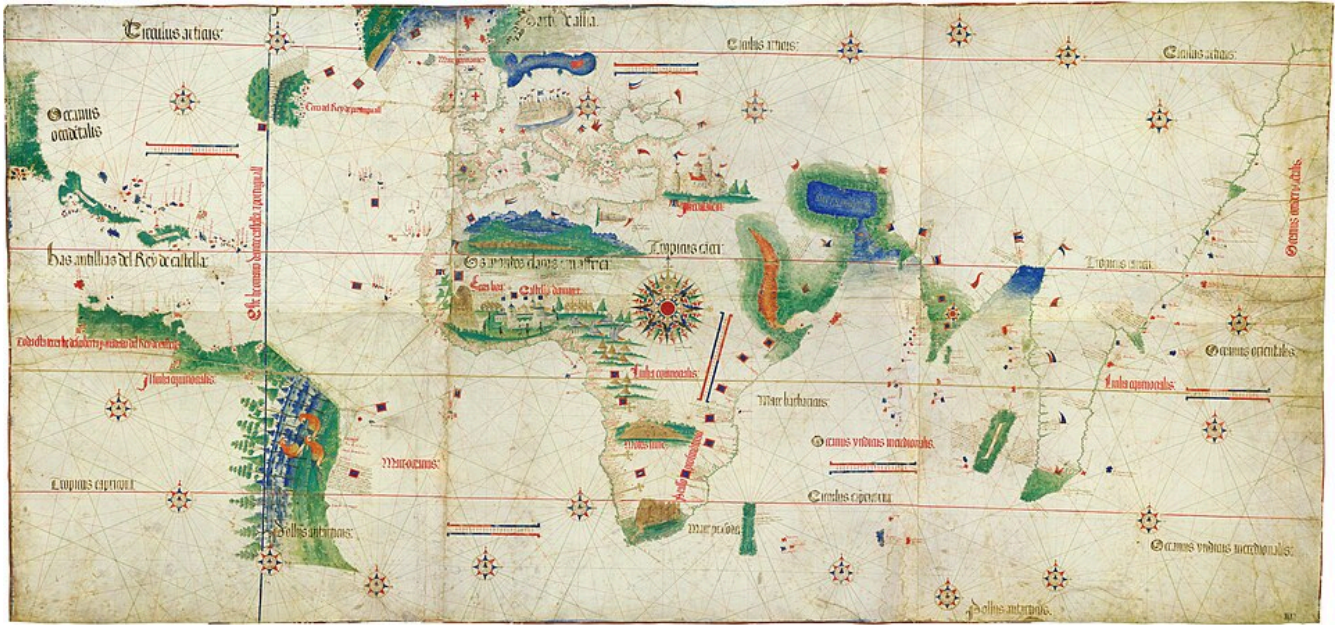
Winter (Nov.–Feb.)



Northeast wind: toward Africa

The monsoon winds of the Arabian Sea change direction with the seasons.

PICTURE STUDY



The Cantino Planisphere, Unknown Portuguese mapmaker, 1502 · Ink, paint and gold on parchment, about 7 feet wide (2.2 m) · Biblioteca Estense Universitaria, Modena, Italy

This is one of the oldest surviving maps to show the discoveries of Dias and da Gama. The Portuguese king guarded his sea charts as state secrets, but in 1502 an Italian agent named Alberto Cantino got this map in Lisbon and smuggled it to his master, Ercole d'Este, Duke of Ferrara. The mapmaker's name is unknown. Africa's outline, taken from real Portuguese voyages, looks almost modern, and the route to India lies open.

The map had adventures of its own. It went missing in 1859, during unrest in Modena, and was later found in a butcher's shop in the city and returned to the library, where it is kept today.

Look closely

- Find Africa. How close is its shape to Africa on your globe? Find the Cape of Good Hope at its southern tip.
- Find the straight lines that cross the map from side to side. Which one is the Equator? Look for the two tropics, too.
- Find the long line running north and south through the Atlantic. It shows the Treaty of Tordesillas (1494), which divided new lands between Spain and Portugal.
- Look for small flags and pillars along the coasts. What might they mean?

Talk about it

1. Why would a king keep his maps secret? Why would another ruler pay to have one smuggled out?
2. Which parts of the world does this map show well, and which are still blank or guessed?

3. How does this map compare with the Martellus map from Lesson 1.2?

PROJECT: THE ROAD TO INDIA: A WIND AND ROUTE MAP

You will measure da Gama's sea road on a globe with a string, and then draw the Portuguese route to India on a large map with its winds. This map is the start of your unit portfolio.

You will need

- A globe (or a large world map), a long piece of string and a ruler
- A large sheet of paper (poster board or taped-together paper), pencil, colored pencils
- An atlas or the lesson map to copy from

Steps

1. On the globe, lay the string from Lisbon down around Africa, along the route on the lesson map, to Calicut in India. Pinch the string where it reaches Calicut.
2. Now lay a second piece of string in a straight line from Lisbon to Calicut across the land of the Middle East. Compare the two lengths. About how many times longer is the sea road?
3. On your large paper, draw the outlines of Africa, Arabia and India, and the Equator. Write the latitudes of Lisbon (39°N), the Cape Verde Islands (15°N), the Cape of Good Hope (34°S), Malindi (3°S) and Calicut (11°N) beside their dots.
4. Draw da Gama's route in red, with the big curve through the South Atlantic. Write the dates beside the stops: left Lisbon July 8, 1497; rounded the Cape November 1497; Malindi April 1498; Calicut May 20, 1498.
5. In blue, draw arrows for the winds: northeast winds off northwest Africa, and the two monsoons over the Arabian Sea, labeled summer and winter.
6. Draw a small caravel or ship near the Cape and a compass rose in a corner.
7. Write a sentence under the map: "The sea road to India was opened by _____ and _____." Fill it with the two things you think mattered most.

Tips

- The string on the globe shows real distances better than a flat map can.
- The overland straight line was shorter, but goods going that way passed through many hands and many tolls. You will learn why that mattered in Lesson 1.4.

Check your work

- My map shows the route in the right order with the dates.
- My map shows the monsoon winds and which way they blow in each season.
- I can explain why the sea road was longer but still worth it.

MAP NOTEBOOK

1. Copy the two monsoon panels: summer wind from the southwest, winter wind from the northeast. Write when da Gama crossed each way.
2. Draw the São Gabriel under sail with its square sails and the red cross on them.
3. Make a timeline from July 8, 1497 to the summer of 1499 with at least six events from the voyage.

From history. In 1572 the Portuguese poet Luís de Camões published *The Lusiads*, a long epic poem about da Gama's voyage to India. Camões had himself sailed to India and the Far East and, it is said, saved his manuscript by swimming ashore with it when he was shipwrecked off the coast of Southeast Asia. The *Lusiads* is still Portugal's national poem.

WORKED EXAMPLES

Example 1. Da Gama left Malindi on April 24, 1498, and reached the coast near Calicut on May 20, 1498. The crossing was about 2,600 miles. How many days did it take, and about how many miles did the ships sail each day?

(Use the map or drawing "The crossing of the Arabian Sea, April-May 1498." shown earlier in this lesson.)

1. Days left in April after the 24th: $30 - 24 = 6$ days.
2. Add the days in May up to the 20th: $6 + 20 = 26$ days.
3. Divide the distance by the days: $2,600 \div 26 = 100$ miles a day (about 160 km a day).

Answer: 26 days, about 100 miles (160 km) a day, a little more than 4 miles an hour, day and night.

Example 2. Da Gama's fleet left the Cape Verde Islands on August 3, 1497, and sighted the coast of southern Africa on November 4. How many days was the fleet out of sight of land?

1. Days left in August after the 3rd: $31 - 3 = 28$ days.
2. All of September: 30 days. All of October: 31 days.
3. Days in November up to the 4th: 4 days.
4. Add: $28 + 30 + 31 + 4 = 93$ days.

Answer: 93 days, about three months out of sight of land.

PRACTICE

1. **EASY** In which city of East Africa did da Gama get a pilot to guide him across the Indian Ocean?

2. **EASY** Which way does the monsoon blow over the Arabian Sea in summer, and which way in winter?
(Use the map or drawing "The two monsoons." shown earlier in this lesson.)
3. **MEDIUM** Malindi is at about 3°S. Calicut is at about 11°N. How many degrees of latitude apart are they, and about how many miles is that north to south?
4. **MEDIUM** Da Gama left Lisbon on July 8, 1497, and reached Calicut on May 20, 1498. About how many months did the voyage out take?
5. **MEDIUM** Look at the route map. Put these stops in the order da Gama reached them: Malindi, Cape of Good Hope, Cape Verde Islands, Mozambique, Calicut, St. Helena Bay, Mombasa.
(Use the map or drawing "Vasco da Gama's route, 1497-1498." shown earlier in this lesson.)
6. **HARD** Going to India, da Gama crossed about 2,600 miles of sea in 26 days. Coming back, the crossing to Africa took about 90 days. About how many miles a day did he average coming back, and why was it so slow?
7. **HARD** A Portuguese sailor in Calicut said they had come "to seek Christians and spices." What two goals does that answer show?
8. **CHALLENGE** Write four sentences judging Vasco da Gama honestly. Include one thing he did well, one thing the monsoon or a local pilot taught you about his success, and one wrong he did.

COMMON MISTAKES

- Thinking da Gama discovered the sea route across the Indian Ocean. Indian, Arab and African sailors had used it for centuries; da Gama was the first to link it by sea to Europe.
- Thinking the shortest line on a map is always the best route. Da Gama sailed far out into the Atlantic, away from Africa, to find better winds.
- Mixing up the monsoons. The summer monsoon blows from the southwest toward India; the winter monsoon blows from the northeast toward Africa.

Make it a game • Monsoon Race. Draw a simple board on paper: Africa on one side, India on the other, with ten squares between. A parent holds a card that says SUMMER on one side and WINTER on the other and flips it every few turns. Each player rolls a die. If the season's wind is blowing your way (summer going to India, winter going home), move the full number; if not, move only 1. First to make the round trip, Malindi to Calicut and back, wins. Talk about it: when would you plan to sail?

Scripture. "They that go down to the sea in ships, that do business in great waters; These see the works of the LORD, and his wonders in the deep." (Psalm 107:23-24, KJV)

The monsoon that turns around twice a year is one of the Lord's wonders in the deep. Sailors of many nations learned to read it, and with it they crossed the ocean.

Practice answers

1. Malindi.
2. In summer it blows from the southwest (toward India); in winter it blows from the northeast (toward Africa and Arabia).
3. They are on opposite sides of the Equator, so add: $3 + 11 = 14^\circ$. $14 \times 69 = 966$ miles (about 1,550 km).
4. From July 8, 1497 to May 8, 1498 is 10 months, plus 12 days: about 10 months (a little over 10 months).
5. Cape Verde Islands, St. Helena Bay, Cape of Good Hope, Mozambique, Mombasa, Malindi, Calicut.
6. $2,600 \div 90 \approx 29$ miles a day. It was slow because he left before the winter monsoon had turned, so the winds were weak or against him.
7. A goal of faith (to find Christian peoples and allies in the East, and spread Christianity) and a goal of trade (to buy spices such as pepper and bring them back to Europe for profit).
8. Sample: Vasco da Gama was a bold and skillful commander who kept his ships together for 93 days out of sight of land. He did not do it alone: he used the monsoon winds that Indian Ocean sailors already knew and a pilot from Malindi who showed him the way. His voyage opened a sea road between Europe and Asia. But on his second voyage in 1502 he burned a ship full of pilgrims, with hundreds of people aboard, which was a cruel and evil act.

1.4 WHY SPICES MATTERED

OBJECTIVES

- Name where pepper, cinnamon, cloves and nutmeg grew in the 1400s and find those places on a map.
- Explain why spices cost so much in Europe: few growing places, great distance, many middlemen, tolls and risk.
- Compute price per ounce and the growth of a price that doubles at each hand-off, and compare spice prices then and now.

Warm-up. Open the spice cupboard. Take out every jar and read the labels. How many spices can you find? Turn each jar over: does the label say where it was grown? Line them up from the one you think came from farthest away to the one you think came from closest. Keep your guesses for the end of the lesson.

Video. Coming soon. The medieval spice trade, pepper, cloves and nutmeg, and the Spice Islands (Banda and the Moluccas): search The History Guy, Smithsonian, Library of Congress and Memoria Press; Homeschool Pop (Alternate).

KEY TERMS

spice

A dried seed, bark, bud, fruit or root used to flavor food, such as pepper, cinnamon, cloves and nutmeg.

Spice Islands

The Moluccas (Maluku), a group of islands in eastern Indonesia where cloves grew, together with the tiny Banda Islands, the only home of nutmeg.

middleman

A trader who buys goods from one person and sells them to another, adding a price for his work, risk and profit.

markup

The amount a seller adds to what he paid for something before he sells it again.

monopoly

Control of all the selling of a good by one seller or group, so buyers cannot shop elsewhere.

price per ounce

The price of a package divided by the number of ounces in it. It lets you compare packages of different sizes fairly.

CORE IDEAS

The story. In the year 408, a Gothic king named Alaric camped outside the walls of Rome and demanded a ransom to go away. He asked for thousands of pounds of gold and silver, silk tunics, scarlet hides, and 3,000 pounds of pepper. Pepper, in a list with gold! A thousand years later, in Henry the Navigator's day, spices were still treasure. In England, a rent could be paid in pepper, and a nobleman's wealth could be counted partly in the pepper and cloves in his storeroom. When da Gama's men said they had come to seek "Christians and spices," every Portuguese listener understood the second word meant riches.

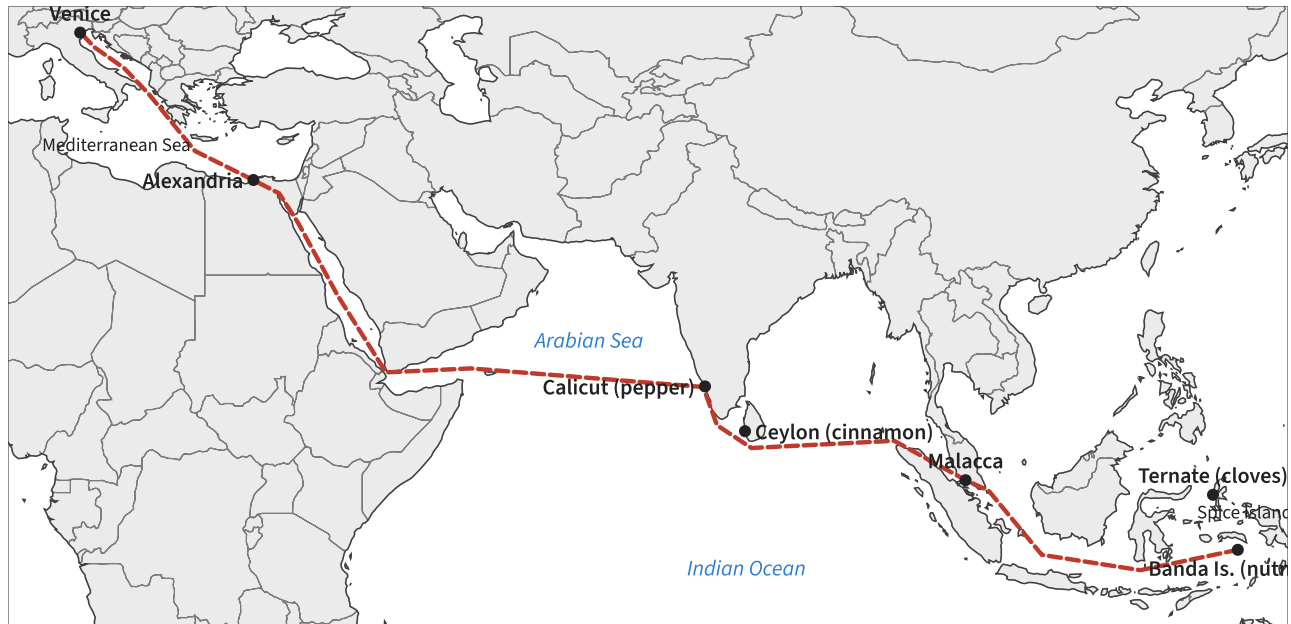
Where they grew. God did not plant spices everywhere. **Black pepper** is the dried berry of a climbing vine that grew in the warm, rainy hills of the **Malabar coast** of southwest India, around Calicut. **Cinnamon** is the inner bark of a tree; the finest came from the island of **Ceylon**, now Sri Lanka. **Cloves** are the dried flower buds of a tree that grew on only a few small islands of the northern **Moluccas**, such as Ternate and Tidore. **Nutmeg** and its lacy covering, mace, came from a single cluster of tiny islands, the **Banda Islands**, so small that the largest is only about 7 miles (12 km) long. These places are hot, wet and near the Equator, and the trees would not grow in the cold of Europe.

How it worked. A bag of cloves from the Moluccas passed through many hands before it reached a kitchen in Europe. Island growers sold to traders who sailed to **Malacca**, the great market on the strait between Sumatra and the Malay Peninsula. From there, merchants carried spices to India, where they joined Malabar pepper in ports like Calicut. Arab ships carried them across the Arabian Sea and up the Red Sea; camel caravans took them to Cairo and down the Nile to **Alexandria**. There the sultans of Egypt taxed them, and merchants of **Venice** bought them and shipped them to Europe. Every trader was a **middleman** who added a **markup** for his labor, his risk of shipwreck and robbery, and his profit, and every ruler along the way took a toll. Venice and Egypt together held something close to a **monopoly** on spices reaching Europe.

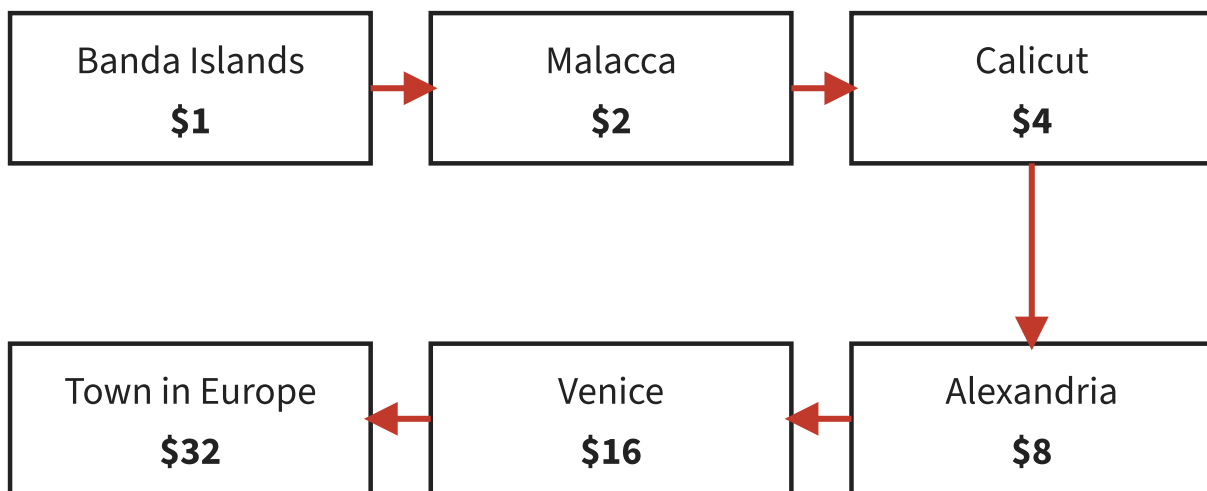
The big idea. Spices were costly for three reasons a geographer can see: they grew in only a few places, those places were very far away, and the road between passed through many hands. If each of five middlemen doubled the price, a bag worth \$1 on the islands would cost \$32 at the end (see the markup diagram). The real markups varied, but you can see why a ship that sailed straight from India to Lisbon, skipping every middleman, could make its owners rich. That is why the Portuguese worked for eighty years to reach India by sea. Many people say Europeans needed spices to hide the taste of spoiled meat. That is mostly a myth: spices often cost more than the meat itself. People prized them for flavor, for medicines, for perfumes, and because owning them showed you were rich.

On the map, and a sad chapter. After da Gama, the Portuguese pushed on. They took Malacca in 1511 and reached the Moluccas the next year. Later the Dutch fought the Portuguese and the English for the spice lands. In 1621 the Dutch East India Company conquered the Banda Islands to control all the nutmeg, and most of the Bandanese people were killed, enslaved or driven from their homes. In 1667, in the peace Treaty of Breda, the Dutch kept the tiny nutmeg island of Run and the English kept New Amsterdam, which they

had already renamed New York. Today pepper is on every kitchen table, and a jar of nutmeg costs a few dollars. The miles are just as long as ever; ships, competition among traders, and spice trees planted in new lands made spices cheap.



Where the spices grew and the old route to Europe (approximate).



Each trader doubles the price (pretend numbers)

A pretend price that doubles at each hand-off. Real markups varied.

PICTURE STUDY



The Pepper Harvest, from the Book of Wonders (Livre des merveilles), Unknown illuminators working in Paris, about 1410–1412 · Paint and gold on parchment, a page in a handwritten book · Bibliothèque nationale de France, Paris (manuscript Français 2810)

The Book of Wonders was a richly painted copy of the travels of Marco Polo and other travelers, made in Paris for John the Fearless, Duke of Burgundy. In one picture the artists show pepper being harvested in southern India, as Marco Polo described it.

The painters had never been to India and had never seen a pepper vine. They painted what they imagined from the words in the book, so the people and plants look European. The picture shows us how precious and mysterious spices seemed to Europeans who used them every week but had no idea how they grew.

Look closely

- Find the people gathering pepper. What are they wearing? Does it look like clothing for a hot country?
- Look at the pepper plants. Real pepper grows on a climbing vine. How did the painters draw it?
- Look for anyone who seems to be a buyer or overseer rather than a worker. How can you tell?
- Look at the colors and the gold. Why would a duke want such a costly book?

Talk about it

1. What did the painters get right, and what did they have to guess?
2. Why might Europeans in 1410 know so little about where their pepper came from?

3. If you painted your own spice cupboard's far-off farms, what would you need to find out first?

Safety first. Ask about food allergies first. Taste only a tiny pinch of each spice and never sniff powder up close; ground spices can make you cough. Do not eat nutmeg by the spoonful: a large amount can make you sick.

PROJECT: SPICE TASTING AND PRICE CHART

You will taste the spices da Gama sailed for, find where each one grows, and work out what each costs per ounce today. Then you will compare them with salt and imagine what they cost in 1498.

You will need

- Small amounts of black pepper, cinnamon, whole cloves and nutmeg (whole or ground); salt for comparison
- Five small plates or paper cups, labels, water and plain crackers
- The jars or a grocery website or store shelf to read prices and net weights in ounces
- Ledger notebook, ruler, pencil, calculator

Steps

1. Set each spice on its own labeled plate. Look at each one whole if you can: a peppercorn, a stick of cinnamon bark, a clove bud, a nutmeg seed. Draw each one.
2. Taste a tiny pinch of each on a cracker. Sip water between tastes. Write one word for each taste (hot, sweet, numbing, warm...).
3. Rule a chart with six columns: Spice, What part of the plant, Where it grew in 1498, Price of jar, Ounces in jar, Price per ounce.
4. Read each jar's price and net weight (or look them up with a parent). Divide price by ounces to get the price per ounce. Round to the nearest cent.
5. Do the same for salt. How many times more costly per ounce is each spice than salt?
6. Make a bar graph of price per ounce, with the bars in order from cheapest to most costly.
7. Write three sentences: Which spice was the most costly today? Which grew in the fewest places in 1498? Why are spices so much cheaper now than then?

Tips

- Net weight is printed on the label as "NET WT" in ounces (oz) and grams (g).
- Whole spices usually cost more per ounce than the same spice in a big ground bag. Compare the same kind if you can.

Check your work

- My chart lists four spices with where they grew and their price per ounce.

- My divisions are correct and rounded to the cent.
- I can explain why spices cost so much more in 1498 than today.

MAP NOTEBOOK

1. Draw a peppercorn, a cinnamon stick, a clove and a nutmeg with its lacy red mace, each labeled with the place it grew.
2. Draw a chain of arrows from the Banda Islands to Venice with the name of each trading city along the way.
3. Draw a map of the Indian Ocean and color in the three spice lands: the Malabar coast, Ceylon and the Spice Islands.

From history. The English phrase “a peppercorn rent” comes from the days when pepper was precious enough to pay rent with. Over the centuries, as pepper grew cheap, a single peppercorn became a token payment, and today the phrase means a very small rent paid only to keep a lease legal.

WORKED EXAMPLES

Example 1. Suppose a 2-ounce jar of ground black pepper costs \$4.00, and a 26-ounce box of salt costs \$1.30. Find the price per ounce of each. How many times more costly per ounce is the pepper?

1. Pepper: $\$4.00 \div 2 \text{ ounces} = \$2.00 \text{ per ounce.}$
2. Salt: $\$1.30 \div 26 \text{ ounces} = \$0.05 \text{ per ounce.}$
3. Compare: $\$2.00 \div \$0.05 = 40.$

Answer: Pepper \$2.00 per ounce, salt \$0.05 per ounce; the pepper costs 40 times as much per ounce. (Use your own store’s prices in the project.)

Example 2. Use the markup diagram. A bag of nutmeg is worth \$1 in the Banda Islands. It passes from the islands to Malacca, to Calicut, to Alexandria, to Venice and to a town in Europe, and its price doubles at each hand-off. How many hand-offs are there, and what is the final price?

(Use the map or drawing “Pretend prices; real markups varied.” shown earlier in this lesson.)

1. Count the arrows: Banda to Malacca, Malacca to Calicut, Calicut to Alexandria, Alexandria to Venice, Venice to the town: 5 hand-offs.
2. Double five times: $\$1 \rightarrow \$2 \rightarrow \$4 \rightarrow \$8 \rightarrow \$16 \rightarrow \$32.$
3. Check: $2 \times 2 \times 2 \times 2 \times 2 = 32.$

Answer: 5 hand-offs; the bag costs \$32, thirty-two times its price on the islands. A ship sailing from Calicut straight to Lisbon skips the hand-offs through Alexandria and Venice.

PRACTICE

1. **EASY** In 1498, what was the only place in the world where nutmeg grew?
2. **EASY** What part of the plant is each: pepper, cinnamon, clove?
3. **EASY** Black pepper grew on which coast of India, and which city on that coast did da Gama reach?
4. **MEDIUM** A bag of pepper costs \$2 in Calicut. If the price doubles at each of 3 hand-offs, what does it cost at the end?
5. **MEDIUM** A 4-ounce jar of whole cloves costs \$10. What is the price per ounce?
6. **MEDIUM** On the spice map, which trading city lies on the narrow strait between Sumatra and the Malay Peninsula? Why was that a good place for a market?
(Use the map or drawing "Where the spices grew and the old route to Europe." shown earlier in this lesson.)
7. **HARD** Give three geographic reasons spices cost so much in Europe in the 1400s.
8. **CHALLENGE** A friend says, "People in the Middle Ages used spices to hide the taste of rotten meat." Write three sentences telling whether this is true and what spices were really used for.

COMMON MISTAKES

- Thinking spices were costly because they were hard to grow. In the right climate the trees grow well; they were costly because they grew in few places, far away, and passed through many hands.
- Believing spices were mainly used to hide spoiled meat. That is mostly a myth.
- Dividing the wrong way for price per ounce. Divide the price by the ounces, not the ounces by the price.

Make it a game • Middleman Market. Players sit in a line: Banda grower, Malacca trader, Calicut merchant, Alexandria merchant, Venice merchant and European cook (parents and siblings can play more than one part). The grower "sells" a bag of nutmeg (a bead or a raisin) for 1 bean. Each trader must sell it to the next for at least double what he paid. The cook pays at the end. Then play again as the Portuguese: a ship carries the bag from Calicut straight to the cook. How much does the cook save? Who loses business?

Scripture. "Lay not up for yourselves treasures upon earth, where moth and rust doth corrupt, and where thieves break through and steal: But lay up for yourselves treasures in heaven, where neither moth nor rust doth corrupt, and where thieves do not break through nor steal: For where your treasure is, there will your heart be also." (Matthew 6:19-21, KJV)

Nations sent ships around the world and fought wars over pepper and nutmeg, which today sit cheaply on every grocery shelf. Earthly treasure changes in value; the treasure Jesus speaks of does not.

Practice answers

1. The Banda Islands, in the Spice Islands of eastern Indonesia.
2. Pepper is a dried berry (fruit) of a vine; cinnamon is the inner bark of a tree; a clove is a dried flower bud.
3. The Malabar coast of southwest India; Calicut.
4. $\$2 \rightarrow \$4 \rightarrow \$8 \rightarrow \$16$. It costs \$16.
5. $\$10 \div 4 = \$2.50$ per ounce.
6. Malacca. Ships sailing between the Spice Islands and India had to pass through that narrow strait, so traders from both sides met there.
7. Any three: they grew in only a few places (Malabar, Ceylon, the Moluccas, Banda); those places were thousands of miles away; the goods passed through many middlemen, each adding a markup; rulers along the way charged tolls and taxes; ships and caravans faced storms, shipwreck and robbery; Venice and Egypt controlled the trade into Europe.
8. Sample: That is mostly a myth. Spices were so costly that they often cost more than the meat, so it would make no sense to waste them on spoiled food, and fresh meat was usually eaten soon after it was killed. People prized spices for flavor, for medicine and perfume, and as a sign of wealth.

UNIT 1 REVIEW

Answer each question. Show your work for calculations and use complete sentences for explanations. Use about 69 miles (111 km) for each degree of latitude. The review is worth 50 points.

1. (5 pts) Who was Henry the Navigator, and how did he help Portugal explore the coast of Africa, even though he made almost no long voyages himself?
2. (5 pts) Why was passing Cape Bojador in 1434 so important? Who did it?
3. (5 pts) Name the great wrong that began on the Portuguese voyages along the African coast in the 1440s, and tell one fact about it.
4. (5 pts) Sagres is at about 37°N and Cape Verde is at about 15°N. About how many miles apart are they north to south?
5. (5 pts) Tell what happened on Bartolomeu Dias's voyage of 1487-1488 and give both names of the cape.
6. (5 pts) The Cape of Good Hope is at about 34°S. About how far is it straight north to the Equator? About how far is it from Lisbon (39°N)?
7. (5 pts) Put these stops on Vasco da Gama's route in order: Calicut, Cape of Good Hope, Lisbon, Malindi, Cape Verde Islands, Mozambique.
8. (5 pts) What is the monsoon, and how did it help da Gama reach India in 1498? Why was his trip home so slow?
9. (5 pts) A ship sails 1,200 miles at 100 miles a day. How many days does it take? How many days would it take at 30 miles a day?
10. (5 pts) A spice worth \$3 at its island passes through 4 middlemen, and each doubles the price. What does it cost at the end? Give two other reasons spices were so costly in Europe.

UNIT PROJECT: THE PORTUGUESE ROAD TO INDIA: MAP AND SPICE CHART

Finish your large wind-and-route map from Lesson 1.3. It should show the coast Henry's caravels explored (with Cape Bojador, 1434, and Cape Verde, 1444), Dias's voyage around the Cape (1488), and da Gama's full route to Calicut (1497-1498), with latitudes beside the main places and arrows for the northeast winds and the two monsoons. Mark where pepper, cinnamon, cloves and nutmeg grew.

Beside the map, mount your spice tasting and price chart from Lesson 1.4 with its bar graph, and write a paragraph of six to eight sentences answering: Why did the Portuguese want a sea road to India, what made it possible, and how should we judge the men who opened it? Name at least one achievement and one real wrong.

- **Accuracy:** Places, latitudes, dates and the order of the route are correct, and the winds point the right way for each season.
- **Calculations:** The spice chart's prices per ounce and the distance figures written on the map are worked correctly and shown.

- **Explanation:** The paragraph explains the spice trade's middlemen, the role of ships and winds, and judges the explorers honestly with a real achievement and a real wrong.
- **Care:** The map and chart are neat, labeled, colored and easy to read, with a title, compass rose and key.

Answer key

1. He was a prince of Portugal (1394-1460), son of King John I. He was the patron of the voyages: from Sagres and Lagos he planned and paid for ship after ship for about forty years, gathered mapmakers and pilots, and had each captain's discoveries put on new charts.
2. Sailors feared no ship could pass Cape Bojador and return, because of shallow, rough seas and strong currents and winds. Gil Eanes passed it in 1434 by swinging wide out to sea and came home safely, which opened the way south along Africa.
3. The slave trade. Portuguese captains seized African people and brought them to Portugal; in 1444 more than two hundred captives were sold at Lagos, and Henry took his share of one fifth. This trade later grew into the Atlantic slave trade that carried millions of Africans across the ocean.
4. $37 - 15 = 22^\circ$; $22 \times 69 = 1,518$ miles (about 2,440 km).
5. A storm carried Dias far south out of sight of land. He sailed east, found no land, turned north and reached Mossel Bay, having rounded Africa without seeing it. His crew made him turn back near the Great Fish River, and on the way home he saw the great cape. By tradition he called it the Cape of Storms; King John II named it the Cape of Good Hope.
6. To the Equator: $34 \times 69 = 2,346$ miles (about 3,770 km). To Lisbon, add across the Equator: $34 + 39 = 73^\circ$; $73 \times 69 = 5,037$ miles, about 5,000 miles (about 8,100 km).
7. Lisbon, Cape Verde Islands, Cape of Good Hope, Mozambique, Malindi, Calicut.
8. The monsoon is a wind over the Indian Ocean that changes direction with the seasons: from the southwest in summer and from the northeast in winter. Da Gama crossed from Malindi to Calicut in spring as the southwest wind rose, so it carried him toward India in less than a month. He started home before the winter wind turned, so the winds were against him and the crossing took nearly three months.
9. $1,200 \div 100 = 12$ days. $1,200 \div 30 = 40$ days.
10. $\$3 \rightarrow \$6 \rightarrow \$12 \rightarrow \$24 \rightarrow \$48$, so \$48. Other reasons (any two): they grew in only a few places; those places were thousands of miles away; rulers along the way charged tolls and taxes; ships and caravans risked storms and robbery; Venice and Egypt controlled the trade into Europe.

WHERE AM I? LATITUDE AT SEA

On land you can ask the way, read a signpost or follow a road. At sea there are no roads, and for weeks there may be nothing to see but water and sky. In this unit you will learn how sailors of the great age of exploration answered the oldest question at sea: **Where am I?** You will sail with Diogo Gomes down the coast of Africa as he measured the North Star with a quadrant around 1460. You will go ashore with Vasco da Gama's pilots at St. Helena Bay in 1497 to measure the noon sun with an astrolabe. You will keep the reckoning with Columbus in 1492 and heave the chip log to count a ship's speed in knots.

You will learn three tools of the navigator: the **height of the North Star**, which gives your latitude at night; the **height of the noon sun**, which gives it by day, even south of the equator; and **dead reckoning**, which uses direction, speed and time to work out how far you have sailed. Then you will see what happens when they are not enough. In 1707 a great British fleet under Sir Cloudesley Shovell was wrecked on the Isles of Scilly because no one aboard could tell how far east they had come. That disaster leads straight to the next unit and the search for longitude.

The stars and the sun keep their courses because God set them there. The series verse reminds us that He also set the peoples of the world in their places: "And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;" (Acts 17:26). The navigators who learned to read the heavens opened the way for merchants, explorers and missionaries to reach those nations, for good and sometimes for ill.

BEFORE YOU BEGIN

- Knows the four cardinal directions and can find north on a map
- Can use a protractor to measure an angle in degrees
- Can multiply and divide whole numbers, such as 24×60 and $42 \div 7$
- Has heard the story of the Portuguese voyages down Africa (Unit 1)

MASTERY CHECKLIST

- I can find the North Star from the Big Dipper and explain why its height equals my latitude.
- I can explain how a quadrant and a mariner's astrolabe measure the height of a star or the sun.
- I can find latitude from the noon sun on an equinox, north or south of the equator.
- I can change degrees and minutes of latitude into nautical miles.
- I can use $\text{speed} \times \text{time} = \text{distance}$ and plot a dead-reckoning course on graph paper.
- I can explain why Shovell's fleet was wrecked in 1707 and why latitude alone was not enough.

OPTIONAL BOOKS AND RESOURCES

- **Stellarium (free planetarium program)** (<https://stellarium.org/>): Free. Shows the night sky from any place on earth at any date. Set your town and find the Big Dipper and Polaris before you go outside (Lesson 2.1), then move yourself to Lisbon or the equator and watch Polaris rise or sink.
- **Royal Museums Greenwich** (<https://www.rmg.co.uk/>): Free to browse. The National Maritime Museum and Royal Observatory have pictures and short articles on astrolabes, quadrants, the 1707 Scilly disaster and the longitude story (Lessons 2.2-2.4 and Unit 3). A parent may preview articles first.

2.1 THE NORTH STAR AND LATITUDE ★ ⚙️

OBJECTIVES

- Tell how Portuguese sailors such as Diogo Gomes measured the height of the North Star as they sailed down the coast of Africa in the 1400s.
- Explain why the height of Polaris above the horizon equals your latitude in the Northern Hemisphere, and find Polaris from the Big Dipper.
- Use latitude to find north-south distances in degrees, nautical miles and land miles.

Warm-up. Stand in the middle of a room and pick a spot high on one wall to be the “North Star.” Point your arm straight at it. Now walk slowly toward that wall, keeping your arm pointed at the spot. Then walk backward, away from it. What happens to the angle of your arm? Talk about why a star that stays still might look higher or lower depending on where you stand.

Watch. *Measuring the altitude of Polaris, the North Star* (Professor Leonard, 1:44).
<https://www.youtube.com/watch?v=-LWls2BMljg>

With the big idea: watch someone measure how high Polaris stands above the horizon, and notice that this angle is about the same as their latitude.

Note: Captions were not available to check; preview it first. It was made for a college GPS class, so it uses a smartphone instead of a quadrant and may be more technical than the lesson.

Backup video. *How to find Polaris? | Star Walk Kids* (Star Walk, 1:06).

<https://www.youtube.com/watch?v=3klOXXKOCfy0>

Before the project: watch how to follow the two pointer stars of the Big Dipper to find Polaris, then try it yourself on a clear night. Note: Captions were not available to check; preview it first. The video ends by promoting the Star Walk Kids app.

KEY TERMS

Polaris (the North Star)

A star that sits almost exactly above the North Pole, so it seems to stay still while the other stars circle around it during the night.

latitude

How far a place is north or south of the equator, measured in degrees from 0° at the equator to 90° at each pole.

horizon

The line where the sky seems to meet the land or the sea.

quadrant

A quarter-circle instrument with sights along one edge and a plumb line, used to measure how high a star or the sun stands above the horizon.

nautical mile

The sailor's mile: one minute ($1/60$ of a degree) of latitude, about 6,076 feet (1.85 km). It is a little longer than a land mile of 5,280 feet.

CORE IDEAS

The story. Around the year 1460, a Portuguese captain named Diogo Gomes sailed south along the coast of West Africa in the service of Prince Henry the Navigator. In his ship he carried a new tool, a wooden **quadrant**. Each clear night he aimed it at the North Star and marked on the wooden face how high the star stood. Years later he told how he had done this, and said that the quadrant was a better guide than his sea chart. His is the oldest written report we have of a sailor measuring a star's height at sea. As the caravels crept farther south, sailors noticed something that frightened some of them: the North Star sank lower in the sky every week. Off the coast of Guinea it hung just above the waves, and near the equator it touched the sea and disappeared.

How it works. The earth spins like a top around an axis that runs from the North Pole to the South Pole. High above the North Pole sits a star called **Polaris**. As the earth turns, every other star in the northern sky seems to wheel around it, making one full circle about every 24 hours, but Polaris stays almost still. If you stood at the North Pole, Polaris would be straight overhead, 90° up. If you stood on the equator, it would sit right on the **horizon**, 0° up. In between, there is a wonderful rule: *the height of Polaris above the horizon equals your latitude*. In Boston, at about 42° north, Polaris is about 42° up. In Miami, at about 26° north, it is about 26° up. Look at the three drawings in the figure to see why.

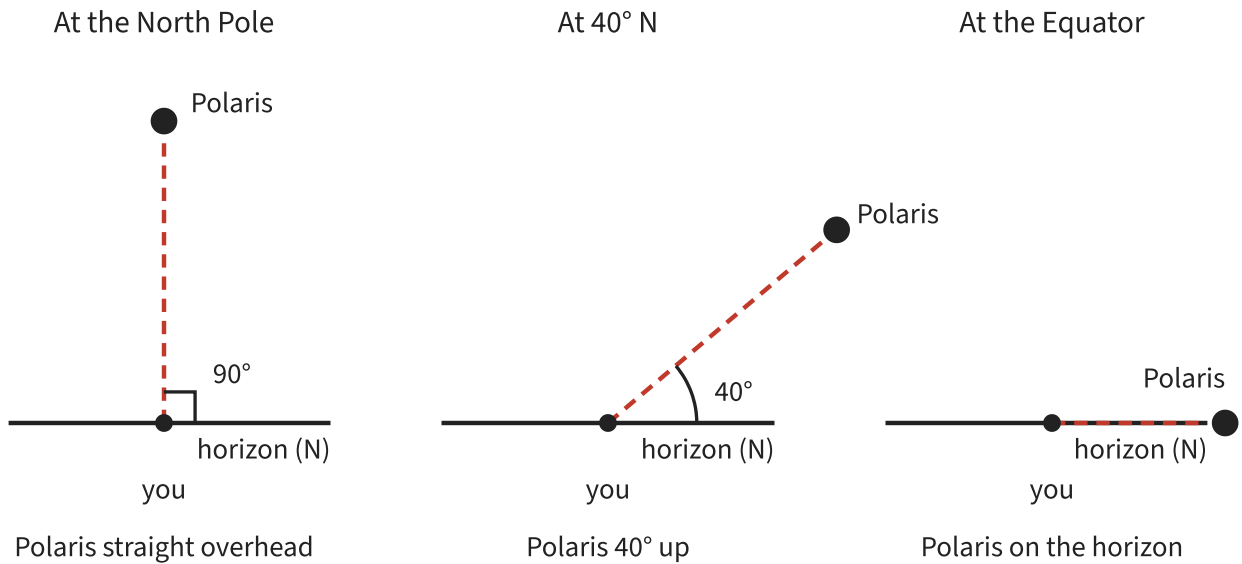
Finding the star. Polaris is not the brightest star in the sky, as many people think. It is only a medium-bright star. To find it, first find the Big Dipper. The two stars at the end of the dipper's cup are called the *pointers*. Draw an imaginary line through them, out of the top of the cup, about five times the distance between them. There you will find Polaris, at the end of the handle of the Little Dipper. When you face Polaris, you are facing north.

The big idea. Latitude tells how far north or south of the equator you are. Lines of latitude, also called parallels, circle the globe like hoops. Each degree of latitude is about 69 land miles (111 km) from the next. Sailors cut each degree into 60 *minutes*, and one minute of latitude is one **nautical mile**, about 6,076 feet. So one degree of latitude is 60 nautical miles. A sailor who knows the latitude of a port and the latitude of his ship can tell how many miles north or south he must sail.

Technology overcoming geography. Before these tools, most sailors stayed within sight of the coast, because the open sea gave no signposts. The quadrant changed that. A pilot could sail north or south until Polaris stood at the height he wanted, and then turn east or west and keep it at that height until his island or cape came into view. Sailors called this "running down the latitude." In the 1400s Polaris was about $3\frac{1}{2}^\circ$ away from the true pole, more than it is today, so Portuguese pilots learned a rule called the Regiment of the North Star. It told them how to correct their reading by looking at two nearby stars called the Guards. But one

problem remained. South of the equator the North Star was gone. You will see in the next lesson how sailors turned to the sun.

On the map. The map shows the coast the Portuguese explored. Lisbon is at about 39° north, Madeira about 33° , Cape Bojador about 26° , Cape Verde about 15° and the fort of Elmina about 5° . A caravel sailing from Lisbon to Elmina would watch Polaris drop from 39° high to only 5° . God set the stars in their places “for signs” (Genesis 1:14), and in this way He gave sailors a lamp to steer by.



The height of Polaris above the horizon equals your latitude.



The coast the Portuguese explored in the 1400s, with lines of latitude.

PICTURE STUDY



Starry Night Over the Rhône, Vincent van Gogh, 1888 · Oil on canvas · Musée d'Orsay, Paris

In September 1888, the Dutch painter Vincent van Gogh set up his easel at night on the bank of the Rhône River in the town of Arles, in southern France. He painted the gas lamps of the town shining across the water and, above them, the stars. Look carefully and you will find seven bright stars in the shape of a dipper. That is the Big Dipper, the same group of stars that sailors used to find the North Star.

Look closely

- Find the seven stars of the Big Dipper. Which way is the cup facing?
- Find the two people walking on the riverbank. Are they looking at the sky?
- Compare the lights of the town with the stars. How did the painter make them look different?
- Look at the brushstrokes in the water. How did he show the reflections?

Talk about it

1. Arles is at about 44° north. How high above the horizon would Polaris be there?
2. Why do you think sailors loved a clear night sky so much?
3. Van Gogh painted the stars bright and large. Is it easier or harder to see stars from a town with many lights? Why?

Safety first. Go stargazing only with an adult. Choose a safe, open spot away from roads and water, and bring a flashlight covered with red cellophane so your eyes stay used to the dark.

PROJECT: A PROTRACTOR-AND-STRAW QUADRANT

You will build a quadrant like the one Diogo Gomes carried and use it to measure the height of the North Star from your own yard. Then you will check your latitude against an atlas. If you get within two or three degrees, you have done as well as many sailors of the 1400s.

You will need

- A plastic protractor with a small hole at the center of its straight edge
- A drinking straw (a stiff one is best)
- Clear tape
- About 12 inches of thread or thin string
- A small weight: a metal washer, a nut or a paper clip
- A pencil and your map notebook
- A flashlight covered with red cellophane
- An atlas or globe showing the latitude of your town

Steps

1. Tape the straw along the straight edge of the protractor so that you can look through it from one end to the other.
2. Tie the thread through the center hole (or tape it at the center mark) and tie the washer to the other end so it hangs below the curved edge like a plumb line.
3. Test your quadrant indoors. Hold the straw level and look through it at a far wall. The thread should hang across the 90° mark. If it does not, retie it.
4. Understand the scale: when the straw is level, the thread reads 90° . When you tip the straw up, the thread moves. The star's height is 90° minus the number where the thread crosses (use the smaller number of the two scales).
5. On a clear night, go outside with an adult. Find the Big Dipper and follow the pointer stars to Polaris.
6. Look through the straw at Polaris. Hold very still while a helper pinches the thread against the protractor and reads the number with the red flashlight.
7. Subtract that number from 90 to get the height of Polaris. Write it in your notebook with the date and time.
8. Take three readings and find the average (add them and divide by 3). This is your latitude by the stars.
9. Look up the latitude of your town in an atlas. How close did you come?

Tips

- Let the washer stop swinging before you read the thread, just as sailors waited for the ship to steady.
- If you cannot find the Big Dipper, it may be low near the horizon. It circles Polaris during the night and through the year, so try again an hour or two later.

- Practice your quadrant in daylight on the top of a tall pole or tree. Never aim it at the sun.

Check your work

- My quadrant reads 90° on the thread when the straw is level.
- I found Polaris by using the pointer stars of the Big Dipper.
- I took three readings, found their average, and compared it with my town's real latitude.

MAP NOTEBOOK

1. Draw the Big Dipper and the Little Dipper. Draw a dotted line from the pointer stars to Polaris and label it.
2. Draw a globe with the equator and the lines of latitude 30° N and 60° N. Draw a tiny sailor at each line and show how high Polaris would be for each one.
3. Copy the map of the African coast. Beside each place, write how high Polaris would stand there.

From history. Polaris has not always been the North Star, and it will not always be. The earth's axis wobbles very slowly, like a spinning top, and traces a great circle in the sky about once every 26,000 years. When the pyramids of Egypt were built, a star called Thuban in the constellation Draco was nearest the pole. Polaris will come closest to the true pole around the year 2100, and in about 12,000 years the bright star Vega will be near the pole instead.

WORKED EXAMPLES

Example 1. A Portuguese pilot sailing south measures Polaris at 33° above the horizon. Which place on the map is at about his latitude?

(Use the map or drawing "Find the place at about 33° north." shown earlier in this lesson.)

1. The height of Polaris equals the latitude, so the ship is at about 33° north.
2. Look along the map for a place at about 33° N.
3. Madeira is at about 33° N.

Answer: He is at about 33° N, the latitude of Madeira.

Example 2. Lisbon is at about 39° N and Cape Verde is at about 15° N. How far apart are they from north to south, in nautical miles and in land miles?

1. Subtract the latitudes: $39^\circ - 15^\circ = 24^\circ$.
2. Each degree is 60 nautical miles: $24 \times 60 = 1,440$ nautical miles.
3. Each degree is also about 69 land miles: $24 \times 69 = 1,656$ land miles (about 2,660 km).

Answer: About 24° , which is 1,440 nautical miles or about 1,656 land miles (about 2,660 km) from north to south.

PRACTICE

1. **EASY** You measure Polaris at 30° above the horizon. What is your latitude?
2. **EASY** Where in the sky is Polaris if you stand on the equator?
3. **EASY** How many nautical miles are in one degree of latitude? How many in one minute?
4. **MEDIUM** Chicago is at about 42° N. How high will Polaris be above the horizon there?
5. **MEDIUM** A ship sees Polaris at 26° (the latitude of Cape Bojador). The captain wants to reach Madeira, at 33° N. Which way must he sail, and about how many nautical miles north or south?
(Use the map or drawing "Cape Bojador and Madeira." shown earlier in this lesson.)
6. **MEDIUM** Using the map, tell how many degrees Polaris would drop in the sky as a caravel sailed from Lisbon (39° N) to Elmina (5° N).
7. **HARD** Why could Portuguese sailors not use Polaris once they sailed south of the equator?
8. **CHALLENGE** In the 1460s Polaris was about $3\frac{1}{2}^\circ$ from the true pole. If a pilot forgot to correct his reading, how many nautical miles off could his latitude be?

COMMON MISTAKES

- Thinking Polaris is the brightest star in the sky. It is only medium-bright; find it with the pointer stars of the Big Dipper.
- Measuring down from straight overhead instead of up from the horizon. The height of a star is always measured up from the horizon.
- Thinking latitude tells how far east or west you are. Latitude tells only north or south; east and west is longitude, the hard problem of the next unit.

Make it a game • Star Height Says. One player is the North Star caller. The caller names a place and its latitude, such as "Miami, 26 degrees!" or "North Pole!" The other players must point an arm at the right height for Polaris: straight up for the North Pole, flat out for the equator, halfway (45°) for a place like Minneapolis. Anyone who points at the wrong height, or points south, sits down. For a hard round, the caller gives only the city name, and players must remember its latitude.

Scripture. “And God said, Let there be lights in the firmament of the heaven to divide the day from the night; and let them be for signs, and for seasons, and for days, and years:”
(Genesis 1:14, KJV)

God made the lights of heaven to be signs. Sailors who measured the North Star were reading one of those signs, and the faithful order of the stars made it possible to find their way across the sea.

Practice answers

1. About 30° N.
2. Right on the northern horizon, 0° high, so it is very hard to see.
3. 60 nautical miles in one degree; 1 nautical mile in one minute.
4. About 42° .
5. North, 7° ($33 - 26 = 7$). $7 \times 60 = 420$ nautical miles.
6. $39 - 5 = 34$ degrees. It would go from about 39° high to only about 5° high.
7. South of the equator Polaris is below the horizon. The round earth hides it, so it cannot be seen at all and cannot be measured.
8. $3\frac{1}{2} \times 60 = 210$ nautical miles. That is why pilots learned the Regiment of the North Star to correct their readings.

2.2 THE ASTROLABE AND THE QUADRANT

OBJECTIVES

- Tell how Vasco da Gama's pilots went ashore at St. Helena Bay in 1497 to measure the sun with an astrolabe, and why sailors needed the sun south of the equator.
- Explain how a quadrant and a mariner's astrolabe measure the height of the sun at noon.
- Find latitude from the noon sun on the day of an equinox, north or south of the equator.

Warm-up. Push a pencil upright into a lump of clay on a sunny windowsill or sidewalk. Mark the tip of its shadow now, and again in 15 minutes. Did the shadow get longer or shorter? What does that tell you about whether the sun is climbing or sinking? (Never look straight at the sun.)

Watch. *How did early Sailors navigate the Oceans?* (thecuriousengineer, 6:20).

<https://www.youtube.com/watch?v=4DlNhbKPiYY>

After the story: watch how sailors used the sun and stars to find how far north or south they were, and look for the astrolabe and quadrant.

Note: Captions were not available to check; preview it first. This video covers early navigation in general, so it may not focus on the astrolabe and quadrant or on the Portuguese voyages.

KEY TERMS

mariner's astrolabe

A heavy brass ring, open so the wind can blow through it, hung from a thumb ring, with a turning sighting arm and a scale of degrees. Sailors used it to measure the height of the sun or a star.

alidade

The turning arm on an astrolabe, with a small hole at each end, that is lined up with the sun or a star.

plumb line

A string with a weight on the end. It always hangs straight down, toward the center of the earth.

noon

The moment when the sun reaches its highest point in the sky for the day and stands due south (in lands well north of the equator) or due north (in lands well south of it).

equinox

One of two days each year, about March 20 and September 22, when the sun stands straight above the equator at noon and day and night are nearly equal everywhere.

declination table

A table telling how far north or south of the equator the sun is on each day of the year. Pilots used it to find latitude from the sun on any day.

CORE IDEAS

The story. In November 1497, after about three months far out on the open Atlantic, Vasco da Gama's little fleet anchored in a wide bay on the southwest coast of Africa. Today it is called St. Helena Bay. The North Star had sunk out of sight long before, when the ships crossed the equator. Now the pilots needed to know exactly how far south they had come. According to the Portuguese historian João de Barros, da Gama went ashore with a large wooden astrolabe, about three hand-spans across, hung from a tripod. On solid ground, away from the rolling deck, his men could measure the height of the noon sun carefully and work out their latitude.

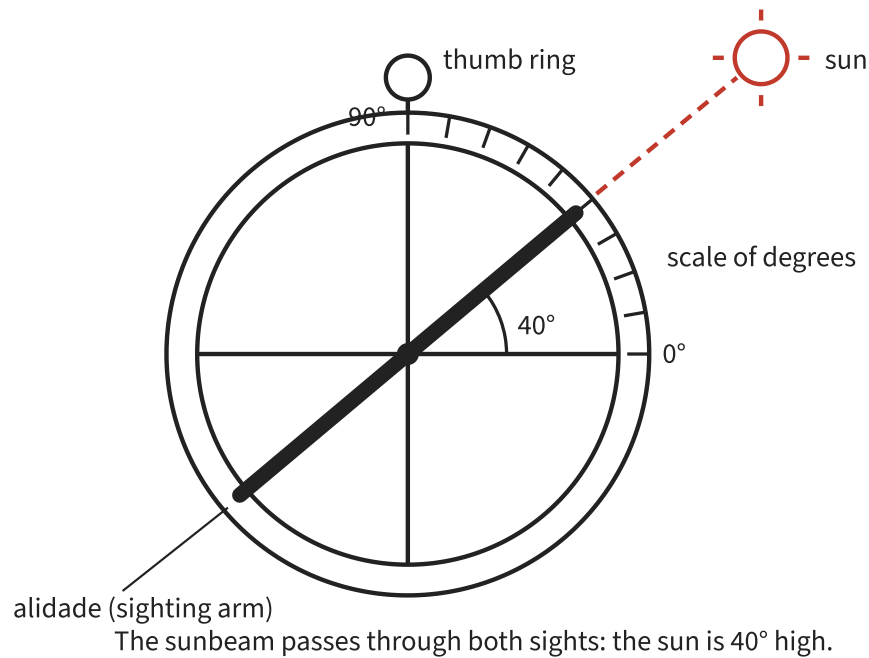
How it worked. Sailors had two main tools. The **quadrant** was a quarter of a circle made of wood or brass. You sighted along one straight edge, and a **plumb line** hanging from the corner crossed a scale of degrees on the curved edge. It worked well for stars, but the wind blew the plumb line about. The **mariner's astrolabe** was a heavy brass ring, open with spokes so the wind could pass through it. The navigator hung it from his thumb so it dangled straight down, then turned the sighting arm, the **alidade**, until a beam of sunlight passed through the hole in the upper sight and fell on the hole in the lower one. He never had to look at the sun. Then he read the sun's height on the scale.

The big idea. Every day the sun climbs, reaches its highest point at **noon**, and sinks again. Navigators measured it again and again around midday and kept the largest number. How high the noon sun stands depends on two things: your latitude and the day of the year. On the two **equinoxes**, about March 20 and September 22, the sun stands straight over the equator, and the rule is simple: *latitude = 90° – the height of the noon sun*. If the noon sun is 50° high, you are at 40°. If the sun is in the south, you are north of the equator. If it is in the north, you are south of the equator. On other days the sun is north or south of the equator by as much as 23½°, so pilots added or subtracted a number from a **declination table**.

The men behind the tables. Some of the best tables came from Abraham Zacuto, a Jewish astronomer from Salamanca in Spain. When Spain drove out its Jews in 1492, he came to Portugal, and his book of tables was printed in Portugal in 1496. Portuguese mathematicians turned his work into simple rules for pilots, called the Regiment of the Astrolabe. But late in 1496 King Manuel ordered the Jews of Portugal to become Christians or leave, and in 1497 many were baptized by force against their will. Zacuto fled. The pilots kept using his tables while the kingdom treated his people with great injustice. Forcing baptism on anyone is a real wrong, for faith in Christ cannot be forced.

Technology overcoming geography. With the astrolabe and the sun, a pilot could find his latitude anywhere in the world, north or south, by day. Portuguese pilots began to mark the latitude of every cape and harbor, so that the next ship could find it. On a pitching deck a reading might be off by a degree or more, which is why da Gama went ashore when he could. Later inventions did better. The backstaff, described by the English sailor John Davis in 1594,

let a navigator stand with his back to the sun and measure its shadow. In the 1700s the octant and the sextant used mirrors to bring the sun right down to the horizon. Look at the figure to see how the astrolabe reads the sun's height.



A mariner's astrolabe. The sighting arm points at the sun, and the scale shows the sun is 40° high.

PICTURE STUDY



The Astronomer, Johannes Vermeer, about 1668 · Oil on canvas · Musée du Louvre, Paris

Johannes Vermeer lived in Delft, in the Netherlands, when Dutch ships sailed to every ocean of the world. In this quiet painting a scholar sits by a window and reaches out to turn a

celestial globe, a globe that shows the stars and constellations instead of the lands. On the table, half hidden by the heavy cloth, lies an astrolabe, and an open book of astronomy. Vermeer painted a companion picture, *The Geographer*, about a year later, with what looks like the same man.

Vermeer loved soft daylight falling through a window. Here the light falls on the scholar's face, his hand and the globe, as if the study of the heavens were itself a kind of light.

Look closely

- Find the celestial globe. Which hand is the scholar using to touch it?
- Find the flat round instrument on the table. That is an astrolabe.
- Where is the light coming from? What does it shine on most brightly?
- Look at the scholar's face. Is he thinking hard, or resting?

Talk about it

1. Why would a man who studied the stars be important to the sea captains of his country?
2. This astronomer works in a quiet room, and the pilots worked on rolling decks. How would their work be different? How would it be the same?

Safety first. Never look straight at the sun, not even for a moment, and never through a straw, tube, binoculars or a homemade instrument. Measure the sun only by its shadow.

PROJECT: MEASURE THE NOON SUN WITH A SHADOW STICK

Sailors measured the sun with an astrolabe. You will measure it safely with a shadow, which is how the ancient Greeks did it. You will find the moment of noon at your house, measure how high the sun stands, and, near an equinox, find your latitude.

You will need

- A straight stick or dowel about 2 to 3 feet long, or a yardstick
- A plumb line (string and a washer) to make the stick stand straight
- Sidewalk chalk, or stones to mark the ground
- A tape measure
- Graph paper, a ruler and a protractor
- A clock or watch and your map notebook

Steps

1. On a sunny day, set the stick upright on flat ground in an open place. Hold the plumb line beside it to make sure it stands straight up.
2. Starting about an hour before midday, mark the tip of the shadow every 10 minutes and write the time beside each mark.

3. Keep going until the shadows start getting longer again. The shortest shadow shows local noon, when the sun is highest.
4. Measure the height of the stick above the ground and the length of the shortest shadow, both in inches.
5. On graph paper, draw a right triangle to scale (1 square = 1 inch, or 1 square = 2 inches for a long stick): a straight-up line for the stick and a flat line for the shadow. Join the top of the stick to the tip of the shadow. That slanted line is the sunbeam.
6. With the protractor, measure the angle where the sunbeam meets the shadow line. That angle is the height of the noon sun.
7. If today is within a few days of an equinox, subtract the angle from 90° to find your latitude. On other days, ask a parent to help you look up the sun's declination for today and add it if it is between March and September, or subtract it if it is between September and March.
8. Compare your answer with your town's latitude in an atlas, and with your North Star reading from Lesson 2.1.

Tips

- The shadow tip moves slowly near noon, so take extra marks every 5 minutes then.
- In almost all of the United States, your shortest shadow will point due north. Mark that line; it is a true north line you can use later.
- If clouds come, record what you have and try again another day, just as sailors had to.

Check your work

- I found the shortest shadow and the time of my local noon.
- I drew the stick and shadow to scale and measured the sun's height with a protractor.
- I used the sun's height to find my latitude, or explained why I needed a table on this day.

MAP NOTEBOOK

1. Draw a mariner's astrolabe and label the thumb ring, the ring, the alidade and the scale of degrees.
2. Draw a ship at the equator, one at 40° N and one at 30° S on the day of an equinox. Show where the noon sun stands for each: overhead, in the south, or in the north.
3. Draw your shadow-stick triangle and write the sun's height beside it.

From history. The oldest mariner's astrolabe yet found came from the wreck of the *Esmeralda*, a ship of Vasco da Gama's second voyage to India, commanded by his uncle Vicente Sodré. The ship sank in a storm in 1503 off the island of Al Hallaniyah, near Oman. Divers brought up a bronze disk in 2014. It bears the Portuguese royal arms and the emblem of King Manuel I, and in 2019 scientists used a laser scan to find faint scale marks on its edge, which showed that it was an astrolabe.

WORKED EXAMPLES

Example 1. On September 22, an equinox, a navigator in Lisbon measures the noon sun at 51° above the southern horizon. What is the latitude of Lisbon?

(Use the map or drawing “How the astrolabe reads the sun’s height. This drawing shows a 40° reading; the ” shown earlier in this lesson.)

1. On an equinox, $\text{latitude} = 90^\circ - \text{the height of the noon sun}$.
2. $90^\circ - 51^\circ = 39^\circ$.
3. The sun is in the south, so Lisbon is north of the equator.

Answer: About 39° N.

Example 2. On the March equinox, a pilot near the Cape of Good Hope measures the noon sun at 56° high, and it stands in the *northern* part of the sky. What is his latitude?

1. $\text{Latitude} = 90^\circ - 56^\circ = 34^\circ$.
2. The noon sun is in the north. That means the sun (over the equator) is north of the ship, so the ship is south of the equator.
3. So the latitude is 34° south.

Answer: About 34° S, the latitude of the Cape of Good Hope.

PRACTICE

1. **EASY** Name the instrument: a heavy brass ring with open spokes, hung from the thumb, with a turning sighting arm.
2. **EASY** How did a navigator line up an astrolabe with the sun without looking at it?
3. **EASY** On an equinox, the noon sun is 60° high in the south. What is your latitude?
4. **MEDIUM** On an equinox, the noon sun is straight overhead, 90° high. Where are you?
5. **MEDIUM** On an equinox, the noon sun is 45° high in the northern sky. What is your latitude?
6. **MEDIUM** Why did Vasco da Gama’s men go ashore at St. Helena Bay to measure the sun?
7. **HARD** Denver is at about 40° N. How high will the noon sun be there on the September equinox, and in which direction will it be?
8. **CHALLENGE** On about June 21 the sun is $23\frac{1}{2}^\circ$ north of the equator. A ship at 40° N measures the noon sun. Will it be higher or lower than on an equinox? How high will it be?

COMMON MISTAKES

- Using any sun reading during the day. Only the noon sun, at its very highest, gives your latitude.

- Forgetting to ask whether the noon sun is in the north or the south. The same height can mean 30° N or 30° S.
- Using the equinox rule on other days. On most days you need the declination table to correct the reading.

Make it a game · Noon Sun Detective. The leader holds a flashlight “sun” at a height and calls out, “Equinox! The noon sun is 70 degrees in the south!” Players race to write the latitude (20° N) on a slate and hold it up. Mix in suns in the north for southern latitudes. A correct answer with the right N or S earns a point; the first to 10 points becomes the leader. For a bonus point, name a real place near that latitude.

Scripture. “Which is as a bridegroom coming out of his chamber, and rejoiceth as a strong man to run a race. His going forth is from the end of the heaven, and his circuit unto the ends of it: and there is nothing hid from the heat thereof.” (Psalm 19:5-6, KJV)

The sun runs its course across the sky so faithfully that a sailor on the far side of the world could measure it and know where he was. The heavens declare the glory of God, and they also guided men home.

Practice answers

1. The mariner’s astrolabe.
2. He turned the alidade until a beam of sunlight passed through the hole in the upper sight and fell on the hole in the lower sight.
3. $90^\circ - 60^\circ = 30^\circ$ N.
4. $90^\circ - 90^\circ = 0^\circ$. You are on the equator (for example, near Quito, Ecuador).
5. $90^\circ - 45^\circ = 45^\circ$. The sun is in the north, so you are at 45° S.
6. On the rolling deck of a ship the astrolabe swung and the reading could be off by a degree or more. On solid ground they could measure carefully with a large astrolabe on a tripod.
7. $90^\circ - 40^\circ = 50^\circ$ high, in the south.
8. Higher, because the sun has moved north, closer to the ship. On an equinox it would be 50° high; now it is $50^\circ + 23\frac{1}{2}^\circ = 73\frac{1}{2}^\circ$ high.

2.3 DEAD RECKONING

OBJECTIVES

- Tell how Christopher Columbus kept track of his ships by dead reckoning in 1492, and how the chip log later measured a ship's speed in knots.
- Use $\text{speed} \times \text{time} = \text{distance}$ to find how far a ship has sailed, in nautical miles.
- Plot a dead-reckoning course on graph paper and find the distance and direction back to port.

Warm-up. Close your eyes and have a parent turn you to face a wall. Walk 5 slow steps forward, turn right, and walk 5 more, counting every step. Before you open your eyes, point to where you started. How close were you? What three things did you use to guess: direction, number of steps, or something else?

Watch. *Chip Log: How Colonial Ships Measured Speed* (Sultana Education Foundation, 3:23). <https://www.youtube.com/watch?v=OmRtfq50meg>

After the story: watch the crew throw the chip log and count the knots as the sand glass runs, the same way Columbus's men measured speed.

Note: Captions were not available to check; preview it first. The video comes from a museum and education group that sails a replica ship. The video shows a colonial-era (1700s) ship, not Columbus's 1492 fleet; the chip log method is the same.

Backup video. *Maritime Dead Reckoning in the 17th Century* (JYF Museums, 14:22).

https://www.youtube.com/watch?v=Bn_70zfwKVI

As review: watch Aaron put heading, speed and time together to mark a ship's position by dead reckoning. Note: Captions were not available to check; preview it first. It runs about 14 minutes and comes from the Jamestown-Yorktown Foundation museums. The video describes 1600s navigation, about a century after Columbus; the method is much the same.

KEY TERMS

dead reckoning

Working out where a ship is from where it started, the direction it sailed, its speed and the time it has sailed.

chip log

A small weighted wooden board tied to a long knotted line. Thrown off the back of a ship, it stays nearly still in the water while the line runs out, showing the ship's speed.

knot

A speed of one nautical mile per hour. Ships and airplanes still measure speed in knots.

sand glass

An hourglass that measures a set time, such as half an hour, or a short glass of about half a minute for the chip log.

traverse board

A wooden board with pegs and holes on which sailors recorded the ship's direction and speed each half hour of a watch.

leeway

The sideways drift of a ship pushed by the wind, so that it does not travel exactly where it is pointed.

CORE IDEAS

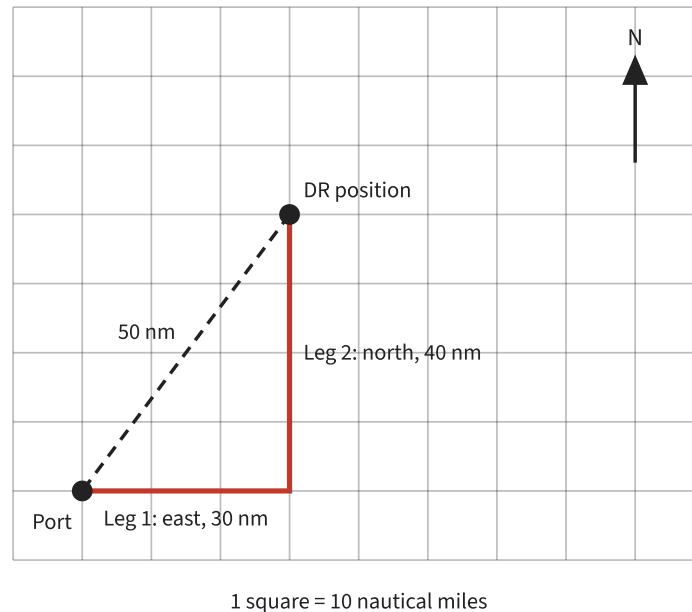
The story. In September 1492, Christopher Columbus sailed west from the Canary Islands with three small ships into a stretch of ocean no European ship had ever crossed. He could measure his latitude now and then, but there was no way at all to measure how far west he had gone. So he kept track by **dead reckoning**. A ship's boy turned a half-hour sand glass all day and night. Each time, the compass heading was noted, and Columbus judged the speed by watching the foam and seaweed slide past the hull. On September 9, according to the summary of his log made later by Bartolomé de las Casas, Columbus decided to tell his crews a smaller number of leagues than he really reckoned, so that they would not be frightened if the voyage grew long. It was a deception, even if he meant it to calm them. Historians who later checked his figures found that he usually guessed his speed too high, so the smaller numbers he gave the crew were actually closer to the truth.

How it worked. Dead reckoning needs three things: *direction*, from the compass; *time*, from the sand glass; and *speed*. Speed was the hardest. By the late 1500s English sailors were using the **chip log**, described in print by William Bourne in 1574. The log was a flat wooden board, weighted along one edge so it floated upright, tied to a long line wound on a reel. A sailor tossed it off the stern. The board stayed nearly still in the water while the ship sailed away from it and the line ran out. Later the line had *knots* tied in it at even spaces, and a sailor counted how many knots slipped through his fingers while a small sand glass ran out. In the method sailors came to use, the knots were 47 feet 3 inches apart and the glass ran 28 seconds, so that the number of knots counted was the ship's speed in nautical miles per hour. That is why a ship's speed is still given in **knots**.

The big idea. Once you know speed and time, you can find distance: $distance = speed \times time$. A ship sailing at 6 knots for 4 hours goes 24 nautical miles. Every half hour, a sailor put a peg in a **traverse board** to mark the compass direction, and at the end of the watch the navigator added it all up and drew the ship's new position on the chart. That mark is the *dead-reckoning position*, or DR position.

The trouble with guessing. Dead reckoning is only as good as its numbers, and the sea plays tricks. Ocean currents carry a ship along without anyone feeling it. The wind pushes it sideways, which sailors call **leeway**. A compass can be off, and a sailor can count wrong. Each error is small, but they add up day after day. That is why a good navigator checked his reckoning every time he could: latitude from the North Star or the noon sun, the depth of the water, the color of the sea, birds and floating weeds that hinted at land.

Technology overcoming geography. With the compass, the sand glass and the log, sailors no longer needed to see land to know roughly where they were. Dead reckoning carried ships across the Atlantic and the Pacific. It is still used today, by ship and airplane pilots, as a backup if GPS fails. When Charles Lindbergh flew alone across the Atlantic in 1927, he found his way by dead reckoning. Look at the figure to see how a navigator plots a course on squared paper: each square stands for 10 nautical miles.



Plotting a dead-reckoning course. Each square is 10 nautical miles.

PICTURE STUDY



The Cannon Shot, Willem van de Velde the Younger, about 1680 · Oil on canvas · Rijksmuseum, Amsterdam

Willem van de Velde the Younger was the son of a Dutch marine artist, and the two of them drew and painted ships all their lives, often sailing out with the fleet to see them. In this painting a large warship fires a gun, perhaps as a signal or a salute, on a calm day. The sea is almost still. The great sails hang loose, waiting for wind.

Van de Velde knew every rope and spar of a ship. Sailors who looked at his paintings could tell which way the wind blew and how the ship was handled.

Look closely

- Find the smoke of the cannon. Which way is it drifting? What does that tell you about the wind?
- Look at the sails. Are they full of wind or hanging loose?
- Find the small boats near the warship. What might they be doing?
- Look at the water. Is it rough or calm?

Talk about it

1. If a sailor on this ship threw out the chip log right now, would many knots run out? Why or why not?
2. On a calm day like this, could a current still move the ship? How would the navigator know?

PROJECT: A LAND CHIP LOG AND A DEAD-RECKONING CHART

You will make a knotted log line and use it to measure the speed of a walking “ship” in the yard, just as sailors measured their speed at sea. Then you will plot a dead-reckoning voyage on graph paper and see how close your reckoning comes to the truth.

You will need

- About 60 feet of string or twine
- A piece of cardboard for the “chip” and a tape measure
- A watch or phone with a second hand, or a homemade sand timer
- A compass (or a compass app) and graph paper
- A ruler, a pencil and colored pencils

Steps

1. Make the log line: tie the cardboard chip to one end of the string. Starting 5 feet from the chip, tie a knot every 5 feet.
2. Go outside with a helper. The helper holds the chip and stands still. That is the water, which stays put while the ship moves.
3. You are the ship. Hold the loose string lightly in your hand and walk steadily away from the helper. When the first knot passes through your fingers, a timer says “Go!”
4. Count the knots that slip through your fingers until the timer calls “Stop!” after 10 seconds. Write down the number.

5. Figure your speed: knots counted $\times$ 5 feet = feet walked in 10 seconds. Try walking slowly and quickly and compare your “knots.”
6. Now plot a voyage on graph paper. Mark Port near the bottom left. Let 1 square = 10 nautical miles. Sail east at 6 knots for 5 hours (30 nm, 3 squares), then north at 8 knots for 5 hours (40 nm, 4 squares). Mark your DR position.
7. Add a third leg of your own choosing. Then measure with a ruler how many squares you are from Port in a straight line, and write the direction home.
8. Finally, have a helper add a “current” that pushed you 1 square north on every leg. Draw your true position in a second color. How far was your reckoning off?

Tips

- Walk at the same steady pace the whole time, as a ship sails steadily, or your speed will change in the middle of the count.
- Keep your graph-paper legs neat: count squares carefully and use a ruler for every line.

Check your work

- My log line has knots spaced evenly, and I measured my walking speed with it.
- My dead-reckoning chart shows Port, each leg with its direction and distance, and the DR position.
- I found the straight-line distance and direction back to Port and showed how a current changed my true position.

MAP NOTEBOOK

1. Draw a chip log: the wooden board, the line on its reel and the sailor counting knots while a sand glass runs.
2. Draw a traverse board with a compass rose of 8 points. Put pegs to show a ship that sailed east for 3 half-hours and northeast for 2.
3. Copy the dead-reckoning chart from the lesson, and add one more leg: west for 2 hours at 5 knots.

From history. Long before the chip log, sailors had another trick called the Dutchman’s log. A sailor at the bow dropped a chip of wood into the water and walked aft beside it along the deck, counting or chanting, until it passed the stern. Knowing the length of the ship and the time it took, he could estimate the ship’s speed. Simple measures like this, used with care and checked every day, carried ships around the world for centuries.

WORKED EXAMPLES

Example 1. A sailor heaves the chip log and counts 6 knots before the sand glass runs out. The ship holds that speed sailing east for 6 hours. How far east has it gone?

1. Six knots counted means the ship's speed is 6 knots, which is 6 nautical miles per hour.
2. Distance = speed $\times$ time = $6 \times 6 = 36$ nautical miles.
3. In land miles that is about $36 \times 1.15 \approx 41$ miles (about 67 km).

Answer: 36 nautical miles east (about 41 land miles, or 67 km).

Example 2. Look at the chart. The ship sailed 3 squares east and then 4 squares north. Each square is 10 nautical miles. How far is the ship from Port in a straight line, and in what direction must it sail to go home?

(Use the map or drawing "Each square is 10 nautical miles." shown earlier in this lesson.)

1. Lay a ruler from the DR position to Port along the dashed line. It measures 5 squares, the same length as 5 squares laid side by side.
2. 5 squares $\times$ 10 = 50 nautical miles.
3. Port is 3 squares west and 4 squares south of the ship, so the way home is mostly south and partly west: between south and southwest.

Answer: About 50 nautical miles, sailing between south and southwest (a little closer to southwest).

PRACTICE

1. **EASY** A ship sails at 5 knots for 4 hours. How far does it go?
2. **EASY** Name the three things a navigator needs to know for dead reckoning, and the tool used for each.
3. **EASY** While the 28-second glass runs, 8 knots of the log line slip through the sailor's hand. What is the ship's speed?
4. **MEDIUM** A ship sails at 7 knots. How many hours will it take to go 42 nautical miles?
5. **MEDIUM** On the chart, the ship now sails west for 2 hours at 5 knots. How many squares does it move, and where is it now compared to Port?
(Use the map or drawing "Each square is 10 nautical miles." shown earlier in this lesson.)
6. **MEDIUM** One nautical mile is about 1.15 land miles. About how many land miles is 40 nautical miles?
7. **HARD** A navigator steers east at 6 knots for 10 hours and plots his DR position 60 nautical miles east of his start. But a current he cannot feel carries the ship north at 1 knot the whole time. Where is the ship really, and how far is the DR position off?

8. **CHALLENGE** In two or three sentences, explain why dead-reckoning errors grow bigger the longer a voyage lasts, and name two ways a navigator could check his position.

COMMON MISTAKES

- Mixing up knots and miles. A knot is a speed (nautical miles per hour), not a distance.
- Forgetting the scale when plotting. Divide the distance by the miles per square before you count squares.
- Trusting the DR position as if it were certain. It is only a careful estimate and must be checked whenever possible.

Make it a game • Blindfold Navigator. Set a “harbor” (a pillow) in a room or yard. The navigator stands at a starting spot, studies the room, and then closes their eyes (with a spotter walking beside them for safety). The navigator gives orders aloud, such as “North 6 steps, then east 4 steps,” and walks them with eyes closed. Then they stop and open their eyes. Measure how many steps they are from the harbor; the closest navigator wins. In round two, allow one “star sight”: the navigator may open their eyes once for two seconds to check their position.

Scripture. “A man’s heart deviseth his way: but the LORD directeth his steps.” (Proverbs 16:9, KJV)

A navigator plans his course with care and marks every hour of it on his chart. But no one can see every current under the sea. We plan wisely and work carefully, and we trust the Lord, who directs our steps.

Practice answers

1. $5 \times 4 = 20$ nautical miles.
2. Direction (the compass), time (the sand glass) and speed (the chip log).
3. 8 knots, which is 8 nautical miles per hour.
4. $42 \div 7 = 6$ hours.
5. $2 \times 5 = 10$ nautical miles = 1 square west. It is now 2 squares (20 nm) east and 4 squares (40 nm) north of Port.
6. $40 \times 1.15 = 46$ land miles (about 74 km).
7. The ship is really 60 nm east and 10 nm north (1×10) of the start. The DR position is about 10 nautical miles off, too far south.
8. Each small error in speed, direction, current or leeway is added to the last one, hour after hour, so on a long voyage they can pile up into many miles. A navigator can check his latitude with the North Star or the noon sun, measure the depth of the water with a lead line, or watch for landmarks, birds and seaweed that show land is near.

2.4 LOST AT SEA: THE SCILLY DISASTER OF 1707

OBJECTIVES

- Tell the true story of Sir Cloudesley Shovell's fleet, wrecked on the Isles of Scilly in October 1707.
- Explain how cloudy skies, dead-reckoning errors, imperfect charts and the lack of any way to find longitude led to the disaster.
- Use latitude in degrees and minutes to compare places and show why latitude alone could not keep the fleet safe.

Warm-up. Lay a few cushions on the floor as “rocks.” Study where they are, then put on a blindfold (with a helper beside you) and try to walk between them to the far wall. Then try again, but this time your helper may call out only “north” or “south” to correct you, never “east” or “west.” Was that enough help? Why not?

Video. Coming soon. The wreck of Sir Cloudesley Shovell's fleet on the Isles of Scilly in 1707 and how it led to the Longitude Act. Search The History Guy, Royal Museums Greenwich (candidate, needs vetting), Smithsonian, Homeschool Pop (Alternate).

KEY TERMS

fleet

A group of warships sailing together under one admiral.

admiral

The officer who commands a whole fleet of ships.

longitude

How far a place is east or west of a starting line, measured in degrees. In 1707 no sailor could measure it at sea.

sounding

Measuring the depth of the water by dropping a weighted line, the lead line, to the bottom.

chart

A map made for sailors, showing coasts, rocks, depths and harbors.

CORE IDEAS

The story. In the autumn of 1707, a British fleet of about twenty warships was sailing home from the Mediterranean Sea under Admiral Sir Cloudesley Shovell. Shovell was one of the most famous sailors in England. Born in Norfolk in 1650, he had gone to sea as a boy and risen to the highest rank. The fleet left Gibraltar at the end of September. For days the sky was gray and stormy, and the navigators could not see the sun at noon or the North Star at night. On October 22 (by the calendar Britain used then), the fleet came up from the

southwest toward the mouth of the English Channel. The ships' masters compared their reckonings. Their answers did not agree, but most believed the fleet was safely clear of land.

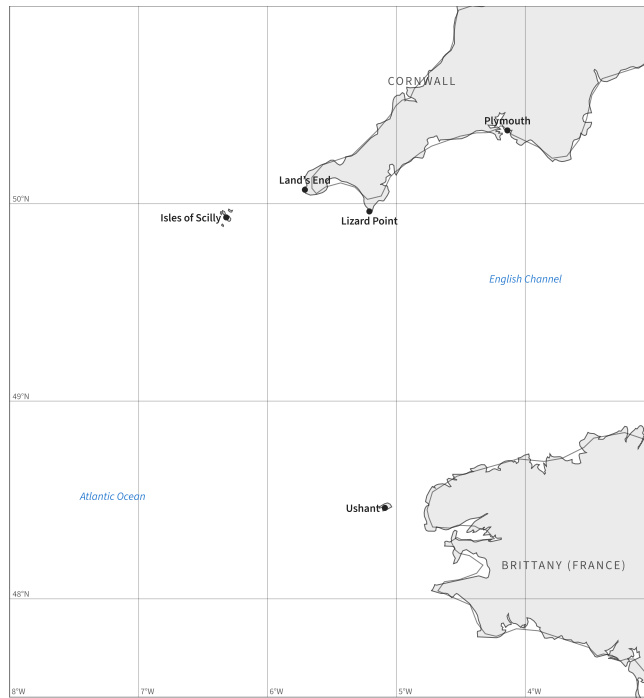
The wreck. That night, at about eight o'clock, in darkness and rough seas, Shovell's flagship, the *Association*, struck the rocks on the western edge of the Isles of Scilly, a cluster of islands and reefs about 28 miles (45 km) west of Land's End, the tip of Cornwall. She sank within minutes, and every man aboard was lost. The *Eagle* and the *Romney* struck rocks and sank too; from the *Romney* only one man is known to have survived. The fireship *Firebrand* was wrecked as well, though some of her crew reached shore. Somewhere between 1,400 and 2,000 men died; the exact number is not known. Shovell's body washed ashore on the island of St. Mary's, and Queen Anne ordered him buried in Westminster Abbey.

How it happened. Many small problems joined together. First, the cloudy days meant no one could measure latitude, so the fleet's north-south position was only a guess. Second, after more than three weeks at sea, the dead-reckoning errors from currents, leeway and wind had piled up. Third, some charts of the time showed the Scilly Isles a little out of their true place. And fourth, there was no way at all to measure **longitude**, so no one could tell how far east the fleet had come. They thought they had open sea ahead. In fact the rocks were right before them. There was a lighthouse on St. Agnes, one of the islands, lit since 1680, but its coal fire was dim on a dark and stormy night.

A story to judge with care. A tale was told many years later that a common sailor warned the admiral that the fleet was near Scilly and was hanged for speaking up. It makes a dramatic story, but no record from 1707 supports it, and historians think it was made up. A good student of history, like a good navigator, asks for evidence before trusting a story.

On the map. Look at the map. The Isles of Scilly lie at about 49° 55' N. Lizard Point, on the Cornish coast, lies at about 49° 58' N, only 3 minutes (3 nautical miles) farther north. The two places have almost the same latitude but lie about 40 nautical miles apart east to west. A navigator who knew his latitude perfectly still could not tell whether he was off the Lizard, safe in the Channel, or about to strike the Scilly rocks. Only longitude could tell him that.

Technology overcoming geography. The loss of Shovell's fleet shocked Britain. It was one of the worst disasters in the history of the Royal Navy, and it was caused not by an enemy but by not knowing where they were. Seven years later, in 1714, Parliament offered a great prize to anyone who could find a practical way to measure longitude at sea. In the next unit you will meet the carpenter who won it.



The western approaches to the English Channel, where Shovell's fleet was wrecked in 1707.

PICTURE STUDY

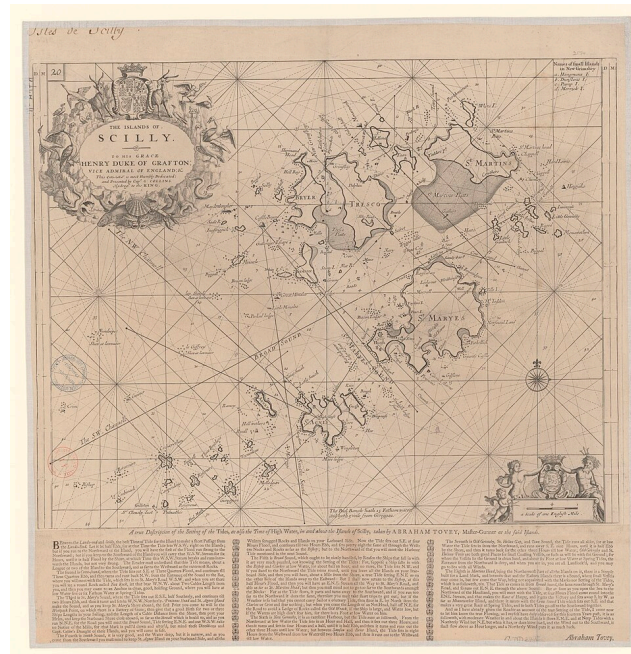


Chart of the Isles of Scilly, from Great Britain's Coasting Pilot, Captain Greenville Collins, 1693 · Engraved sea chart in a printed atlas · This copy: Bibliothèque nationale de France, Paris; copies survive in many libraries and map collections

Greenville Collins was a Royal Navy captain whom King Charles II sent, in 1681, to survey the coasts and harbors of Britain. For about seven years he sailed around the island, measuring and sounding. In 1693 his charts were printed together as *Great Britain's*

Coasting Pilot, the first sea atlas of the British coasts made from a real survey. This is the kind of chart the officers of 1707 relied on.

Collins worked carefully with the tools of his day, but without a way to measure longitude, even a good chart could place islands a little out of their true position, and a chart could not tell a captain where his own ship was.

Look closely

- Find the tiny numbers in the sea. They are soundings, the depth of the water. Where is the water shallowest?
- Find the rocks scattered around the islands. Which side of the islands looks most dangerous?
- Find the compass rose and the straight lines that run out from it. What would a sailor use them for?
- Find the title panel. What decorations did the engraver add?

Talk about it

1. Why would a chart full of soundings help a captain in fog or darkness?
2. Even the best chart could not save Shovell's fleet. What did the officers need to know that no chart could tell them?

Safety first. When you walk blindfolded, always have a helper walk beside you, keep away from stairs, steps, water and hard furniture, and move slowly.

PROJECT: FOG WALK: HOW ERRORS GROW

You will play navigator in a pretend fog. You will plan a course across the yard on graph paper, walk it by dead reckoning with your eyes closed, and measure how far you drift. Then you will see how much a single "star sight" helps, and why a fleet in cloudy weather was in such danger.

You will need

- Graph paper, a ruler and a pencil
- A compass or compass app
- Four or five cushions, buckets or pillows for "rocks" and a hula hoop or towel for the "harbor"
- A blindfold or sleep mask and a helper
- A tape measure and your notebook

Steps

1. Measure your normal walking step: walk 10 steps, measure the distance, and divide by 10.

2. Set up the yard: a starting spot, a harbor about 40 to 60 feet away, and the rocks in a group near the route.
3. Draw a chart of the yard on graph paper (for example, 1 square = 5 feet), with the start, the rocks and the harbor. Plan a safe course in two or three legs, each with a compass direction and a number of steps.
4. Fog voyage: blindfolded, with your helper beside you, walk your planned legs, using only your step count and turning by the compass directions your helper sets you on at each corner.
5. Stop at the end. Take off the blindfold and measure how far you are from the harbor and whether you passed near the rocks. Mark your real end point on your chart in a second color.
6. Second voyage: do it again, but halfway through you may lift the blindfold for two seconds to see one landmark, like a sailor getting one look at the North Star. Did it help?
7. Write three sentences comparing the two voyages and explaining what Shovell's fleet lacked.

Tips

- Walk at your normal pace; short or long steps throw your count off, just as a wrong guess of speed throws off a ship's reckoning.
- Use soft things for rocks so no one gets hurt.

Check your work

- My chart shows the planned course with directions, steps and a scale.
- I measured and recorded how far off I was on both voyages.
- I explained how a single sight of a landmark or star corrects dead reckoning, and what the Scilly fleet was missing.

MAP NOTEBOOK

1. Draw the map of the Isles of Scilly and the tip of Cornwall. Label the Scilly Isles, Land's End and Lizard Point, and write the latitude of each.
2. Draw the *Association* under full sail, and below it write the four reasons the fleet was lost.
3. Draw a lead line with its weight and mark it in fathoms (1 fathom = 6 feet).

From history. For more than 250 years the wreck of the *Association* lay hidden under the waves of the Western Rocks. In 1967, divers found the wreck site and brought up cannons, coins and other objects from the ship. Some of them can be seen today in museums in the Isles of Scilly and Cornwall, reminders of the night a whole fleet was lost for want of knowing its longitude.

WORKED EXAMPLES

Example 1. The Isles of Scilly are at about $49^{\circ} 55' \text{ N}$, and Lizard Point is at about $49^{\circ} 58' \text{ N}$. How far apart are they from north to south, in nautical miles? What does this show?

(Use the map or drawing “The Scilly Isles and Lizard Point lie at nearly the same latitude.” shown earlier in this lesson.)

1. Subtract the minutes: $58' - 55' = 3'$.
2. One minute of latitude is one nautical mile, so they are 3 nautical miles apart from north to south.
3. That is almost the same latitude. A navigator who knew his latitude exactly could still not tell whether he was near the Lizard or near the Scilly rocks, about 40 nautical miles to the west.

Answer: Only 3 nautical miles apart north to south. Latitude alone could not tell them apart; the fleet needed longitude.

Example 2. Suppose a fleet’s dead reckoning slips 6 nautical miles off course each day in the same direction, and the clouds hide the sun and stars for 8 days. How far off could its reckoning be?

1. The errors add up, day after day: 6 nautical miles $\times$ 8 days.
2. $6 \times 8 = 48$ nautical miles.
3. In land miles: $48 \times 1.15 \approx 55$ miles (about 89 km).

Answer: About 48 nautical miles (about 55 land miles), more than the distance from Scilly to the Lizard.

PRACTICE

1. **EASY** Who commanded the British fleet wrecked on the Isles of Scilly in 1707, and what was his flagship?
2. **EASY** Name the four ships lost in the disaster.
3. **EASY** Why could the navigators not measure their latitude in the days before the wreck?
4. **MEDIUM** Ushant, an island off France, is at about $48^{\circ} 28' \text{ N}$. The Isles of Scilly are at about $49^{\circ} 55' \text{ N}$. How far apart are they from north to south, in degrees and minutes and in nautical miles?
(Use the map or drawing “Ushant and the Isles of Scilly guard the mouth of the English Channel.” shown earlier in this lesson.)
5. **MEDIUM** Name four problems that together led to the wreck of Shovell’s fleet.
6. **MEDIUM** The Isles of Scilly lie about 28 miles west of Land’s End. About how many kilometers is that? (1 mile $\approx$ 1.6 km.)

7. **HARD** A ship sailing east at 5 knots believes the nearest rocks are 60 nautical miles ahead. In truth they are only 30 nautical miles ahead. How many hours does the captain think he has, and how many does he really have?
8. **CHALLENGE** A popular story says a sailor warned Shovell and was hanged for it. No record from 1707 supports the story. In two or three sentences, explain how a careful historian should treat a story like this.

COMMON MISTAKES

- Thinking the fleet was wrecked by an enemy or by careless sailors. It was wrecked by uncertainty: skilled men could not measure where they were.
- Thinking that knowing latitude is enough. Places at the same latitude can be many miles apart east to west.
- Repeating the hanged-sailor story as fact. It is a later legend with no evidence from 1707.

Make it a game · Latitude or Longitude? The leader reads a clue aloud, such as “I can tell you how far north you are,” “I tell you how far east you are,” “The North Star gives me,” “Sailors in 1707 could not measure me,” or “The noon sun on an equinox gives me.” Players shout “Latitude!” or “Longitude!” A right answer earns a step toward a “harbor” across the room; a wrong answer sends you back one step onto the “rocks.” The first player to reach the harbor wins.

Scripture. “There is a way which seemeth right unto a man, but the end thereof are the ways of death.” (Proverbs 14:12, KJV)

The fleet’s course seemed right to its officers, yet it led onto the rocks. In navigation and in life, feeling sure is not the same as being right. Wisdom checks its reckoning against the truth, and humbly asks God for guidance.

Practice answers

1. Admiral Sir Cloudesley Shovell; his flagship was the *Association*.
2. The *Association*, the *Eagle*, the *Romney* and the fireship *Firebrand*.
3. The sky was cloudy and stormy, so they could not see the noon sun or the North Star.
4. $49^{\circ} 55' - 48^{\circ} 28' = 1^{\circ} 27'$. That is $60 + 27 = 87$ minutes, or 87 nautical miles.
5. Cloudy weather that hid the sun and stars; dead-reckoning errors that piled up over weeks at sea; charts that showed Scilly slightly out of place; and no way to measure longitude.
6. $28 \times 1.6 = 44.8$, about 45 km.
7. He thinks $60 \div 5 = 12$ hours; he really has only $30 \div 5 = 6$ hours before reaching the rocks.
8. A careful historian asks what evidence supports a story and when it was first told. This tale appeared many years after the wreck with no record from the time behind it, so it should be treated as a legend, not as fact, however exciting it sounds.

UNIT 2 REVIEW

Answer each question. Show your work for calculations and use complete sentences for explanations. You may use a ruler and protractor. The review is worth 50 points.

1. (5 pts) How do you find Polaris in the night sky? Is it the brightest star?
2. (5 pts) A sailor measures Polaris at 33° above the horizon. What is his latitude? How high would Polaris be at the North Pole and at the equator?
3. (5 pts) Lisbon is at about 39° N and Elmina is at about 5° N. How far apart are they from north to south in degrees and in nautical miles?
4. (5 pts) Describe a mariner's astrolabe and tell how a navigator measured the sun with it without looking at the sun.
5. (5 pts) On an equinox, the noon sun is 52° high in the southern sky. What is your latitude? What would it be if the sun were 52° high in the northern sky?
6. (5 pts) Why did Portuguese pilots need the sun once they sailed south of the equator? Who made the tables they used to find latitude from the sun, and what wrong was done to him and his people in Portugal?
7. (5 pts) What is a knot? How did the chip log measure a ship's speed?
8. (5 pts) On graph paper where 1 square = 10 nautical miles, a ship sails east at 5 knots for 6 hours, then north at 8 knots for 5 hours. How many squares is each leg? How far is the ship from port in a straight line?
9. (5 pts) Who commanded the fleet wrecked on the Isles of Scilly in 1707? Give three reasons the navigators did not know where they were.
10. (5 pts) The Isles of Scilly are at about $49^\circ 55'$ N and Lizard Point is at about $49^\circ 58'$ N. How many nautical miles apart are they from north to south? Explain why this shows that latitude alone could not keep the fleet safe.

UNIT PROJECT: MY NAVIGATOR'S LOGBOOK

Make a navigator's logbook that gathers your work from this unit. Include your protractor-and-straw quadrant (or a careful drawing of it) and a log page of your North Star readings with dates, times and the average; your shadow-stick drawing and noon-sun measurement; and your dead-reckoning chart on graph paper with each leg labeled by direction, speed, time and distance, your DR position and the true position with a current added.

Finish with a one-page "report to the Admiralty" about the Scilly disaster of 1707, with a small map of the Isles of Scilly and Cornwall labeled with latitudes. Explain what went wrong, which tools the navigators had, and what tool they still needed.

- **Measurements:** Star and sun readings are recorded with dates and times, averaged correctly, and compared with the true latitude of home.
- **Dead-reckoning chart:** The chart has a scale, a north arrow, correctly computed and plotted legs, and the distance and direction back to port.

- **Explanation:** The Scilly report explains latitude, dead reckoning and the missing longitude clearly and accurately, and tells the story truthfully.
- **Care:** The logbook is neat, labeled and easy for someone else to follow.

Answer key

1. Find the Big Dipper and follow the two pointer stars at the end of its cup, about five times the distance between them, to Polaris at the end of the Little Dipper's handle. It is not the brightest star; it is only medium-bright.
2. His latitude is about 33° N. At the North Pole Polaris is 90° high (straight overhead); at the equator it is 0° , on the horizon.
3. $39 - 5 = 34^\circ$. $34 \times 60 = 2,040$ nautical miles.
4. It is a heavy brass ring, open with spokes so the wind blows through, hung from a thumb ring so it hangs straight down, with a scale of degrees and a turning sighting arm (the alidade). The navigator turned the alidade until sunlight passed through the hole in the upper sight onto the hole in the lower sight, then read the sun's height on the scale.
5. $90^\circ - 52^\circ = 38^\circ$. With the sun in the south, 38° N. With the sun in the north, 38° S.
6. South of the equator the North Star is below the horizon and cannot be seen. Abraham Zacuto, a Jewish astronomer, made the tables (printed in Portugal in 1496). In 1496-1497 King Manuel ordered the Jews to convert or leave, many were baptized by force, and Zacuto fled.
7. A knot is a speed of one nautical mile per hour. The weighted log board was thrown off the stern and stayed nearly still in the water while the knotted line ran out; sailors counted the knots that ran out while a small sand glass emptied, and the number of knots was the speed.
8. Leg 1: $5 \times 6 = 30$ nm = 3 squares east. Leg 2: $8 \times 5 = 40$ nm = 4 squares north. The straight line back to port measures 5 squares = 50 nautical miles.
9. Admiral Sir Cloudesley Shovell. Any three: cloudy weather hid the sun and stars so they could not measure latitude; dead-reckoning errors had piled up over weeks at sea; some charts showed Scilly slightly out of place; there was no way to measure longitude.
10. $58' - 55' = 3'$, which is 3 nautical miles. The two places have nearly the same latitude but are about 40 nautical miles apart east to west, so a navigator who knew only his latitude could not tell whether he was in safe water near the Lizard or heading onto the Scilly rocks. He needed his longitude.

THE LONGITUDE PROBLEM

In Unit 2 you learned that a sailor can find his latitude from the North Star or the noon sun, and you saw what happened at the Isles of Scilly in 1707 when a fleet did not know where it was. Latitude was only half the answer. For centuries no one at sea could tell how far east or west he had sailed, and ships ran onto rocks or wandered for weeks looking for islands they could not find. In 1714 the British Parliament offered a fortune to anyone who could solve the **longitude problem**.

The answer came from an unexpected place: a carpenter from Lincolnshire named John Harrison, who spent about thirty years building four sea clocks, ending with the small watch called H4. You will learn the beautiful idea behind his work: the earth turns 15° every hour, so **time tells place**. You will catch local noon with a shadow stick and work out your own longitude, and you will sail with Captain Cook as a copy of H4 is tested for three years across the southern seas.

Scripture says that God “hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation” (Acts 17:26). Times and places are both in His ordering. In this unit you will see how the steady turning of the earth He made lets us measure one by the other.

BEFORE YOU BEGIN

- Can find latitude on a globe and explain how the North Star shows it (Unit 2)
- Can multiply by 15 and divide by 4
- Can tell time to the minute, including a.m. and p.m.
- Knows the four cardinal directions and can find them on a map

MASTERY CHECKLIST

- I can explain why latitude was easy to find at sea and longitude was hard, and what the Longitude Act of 1714 offered.
- I can tell the story of John Harrison and his clocks H1 to H4, and explain how he beat the rolling of the ship and changes of temperature.
- I can turn a time difference into longitude: 15° for each hour and 1° for each 4 minutes, east or west.
- I can read a map of time zones and longitude lines.
- I can tell how Captain Cook tested K1, the copy of H4, on his second voyage (1772–1775).
- I can find my own longitude from the time of local noon.

OPTIONAL BOOKS AND RESOURCES

- **time.gov (National Institute of Standards and Technology)** (<https://www.time.gov/>): Free. The official U.S. time, to the second. Use it to put a watch on trial (Lesson 3.2) and to time local noon (Lesson 3.3).
- **Royal Museums Greenwich** (<https://www.rmg.co.uk/>): Free to browse. The museum that keeps Harrison's H1 to H4 and Kendall's K1 at the Royal Observatory, with photographs and short articles on the longitude story. A parent may choose the pages.
- **NOAA Solar Calculator** (<https://gml.noaa.gov/grad/solcalc/>): Free. Gives the "equation of time" and the time of solar noon for any place and date, so you can correct and check your shadow-stick measurement (Lesson 3.3).

3.1 THE LONGITUDE PRIZE ★ ⚙️

OBJECTIVES

- Tell how the Scilly disaster of 1707 led Parliament to offer the Longitude Prize in 1714, and what the prize asked for.
- Explain why latitude was easy to find at sea and longitude was very hard.
- Change degrees of longitude into nautical miles and into minutes of clock time.

Warm-up. Take a globe or a world map and put your finger in the middle of the Atlantic Ocean. Use the lines that run east and west to say how far north you are. Now imagine the ocean has no painted lines at all, only water in every direction. Close your eyes and turn around three times. Which way is east? How far east or west of home are you? Talk about what you would need to know to answer.

Watch. *The longitude problem: history's deadliest riddle* (Map Men, 9:16).

<https://www.youtube.com/watch?v=3mHC-Pf8-dU>

After the story: watch why longitude was so hard to find at sea and how shipwrecks like Shovell's in 1707 led to the Longitude Act of 1714.

Note: Captions were not available to check; preview it first. Map Men is a British comedy channel whose jokes are sometimes cheeky, and it opens with a plug for their book.

KEY TERMS

longitude

How far east or west a place is from the prime meridian, measured in degrees from 0° to 180° east or west.

meridian

A line of longitude running from the North Pole to the South Pole.

prime meridian

The meridian of 0° longitude. Today it runs through the Royal Observatory at Greenwich, near London.

nautical mile

The sailor's mile: one minute (1/60 of a degree) of latitude, about 1.15 ordinary miles (1.85 km). One degree is 60 nautical miles.

Board of Longitude

The group of men named by the Longitude Act of 1714 to judge new methods of finding longitude and to give out the prize money.

CORE IDEAS

The story. In June of 1714 a committee of the House of Commons in London sat down to listen to the most famous scientist in England, Sir Isaac Newton, then seventy-one years old.

The question before them was an old one: how can a ship far out at sea know how far east or west it has sailed? Everyone in the room remembered October 1707, when Admiral Sir Cloudesley Shovell's fleet ran onto the rocks of the Isles of Scilly at night and well over a thousand sailors drowned (you met that story in Unit 2). Two mathematicians, William Whiston and Humphry Ditton, had asked Parliament to offer a reward for a solution. Newton explained the methods people had suggested and told the committee plainly that none of them was ready to use at sea. In July 1714 Parliament passed the **Longitude Act**, and Queen Anne gave her consent only weeks before she died.

What the prize asked. The Act offered £20,000 to anyone who could find longitude at sea to within half a degree. A method good to two-thirds of a degree would win £15,000, and one good to a whole degree would win £10,000. That was a fortune, more than a skilled workman could earn in many lifetimes. The method had to be proved on a real voyage from Great Britain to the West Indies, a trip of about six weeks. A group of judges, later called the **Board of Longitude**, would decide who had earned it. The prize was open to anyone at all: a professor, a sea captain or a village carpenter.

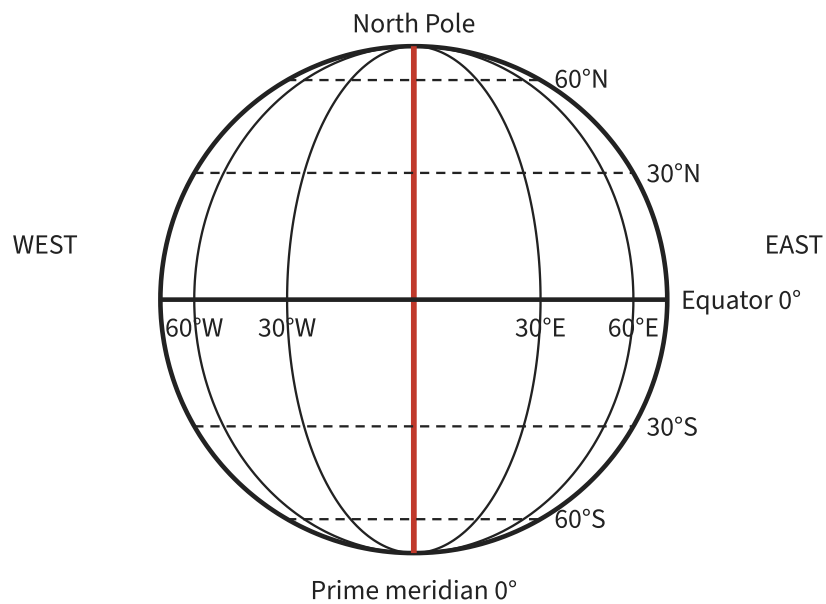
Why it was so hard. Finding **latitude** was easy for a good navigator. God set the North Star almost exactly over the North Pole, so its height above the horizon tells how far north you are, and the noon sun can be measured the same way. But **longitude** has no natural starting line. The earth turns from west to east, all the way around (360°) in 24 hours, so every star and the sun look the same from every meridian, just at a different time. The key is time: $360^\circ \div 24 \text{ hours} = 15^\circ \text{ every hour}$. If a sailor knew the time at home and the time where his ship was at the very same moment, the difference would tell his longitude. A Dutch scholar, Gemma Frisius, had suggested carrying a clock to sea as early as 1530. The trouble was that no clock could keep good time on a rolling, pitching ship, through heat and cold and salty damp. Pendulum clocks, invented by Christiaan Huygens in 1656, kept fine time on a steady wall, but at sea the waves threw the pendulum off its beat.

Other ideas. Galileo had found four moons circling Jupiter in 1610. Their comings and goings could serve as a clock in the sky, and on land the method worked well. But no one could hold a telescope steady on a tiny moon from a heaving deck. Another idea was the **lunar distance** method: the moon moves steadily against the stars, so measuring the gap between the moon and a bright star can tell the time at home. That needed very exact tables of the moon and stars and hours of careful arithmetic. King Charles II had founded the Royal Observatory at Greenwich in 1675 partly to make such tables.

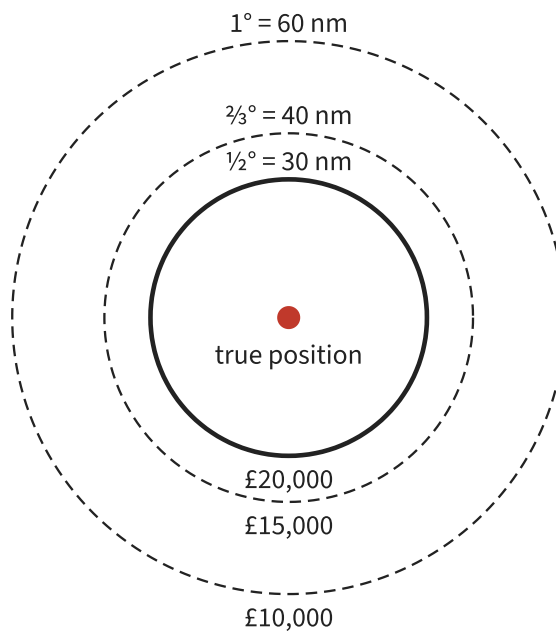
On the map. At the equator, one degree of longitude is 60 nautical miles, about 69 miles (111 km). So half a degree is 30 nautical miles. Since the earth turns 15° an hour, it turns 1° every 4 minutes, and half a degree every 2 minutes. To win the top prize with a clock, the clock could not drift more than about 2 minutes during the whole six-week voyage. That is about 3 seconds a day.

Technology overcoming geography. The open ocean has no signposts, no rivers and no hills. For centuries that sameness was a deadly danger. The Longitude Prize asked a simple,

bold question: could human skill turn the blank sea into a grid where every ship knew its place? In the next lesson you will meet the man who answered it.



Parallels of latitude run east and west; meridians of longitude run from pole to pole. The red line is the prime meridian, 0°.



The three prize levels of 1714, measured at the equator. The closer the method came to the ship's true position, the bigger the prize.

PICTURE STUDY



Portrait of Sir Isaac Newton, Sir Godfrey Kneller, 1702 · Oil on canvas · National Portrait Gallery, London

Godfrey Kneller was born in Germany and became the leading portrait painter in England, painting kings, queens and great men. He painted Isaac Newton more than once. In this portrait from 1702 Newton was about sixty years old and already famous for his laws of motion and his law of gravity. Twelve years later the same man would stand before Parliament and explain why finding longitude at sea was still an unsolved problem.

Newton was a Bible reader as well as a scientist, and he believed the steady, orderly motions of the heavens showed the wisdom of their Maker. Those same orderly motions were what the longitude hunters hoped to use.

Look closely

- Look at Newton's face and eyes. What kind of person does he seem to be: hasty or thoughtful, proud or calm?
- Look at his long curled hair. Gentlemen of Newton's day often wore wigs like this.
- Look at the background. Does the painter show any books or scientific tools? What does he want you to notice instead?
- Find where the light falls brightest. Why might a painter light a scientist's face this way?

Talk about it

1. Newton told Parliament that no clock good enough for the sea had yet been made. Why do you think Parliament still offered the prize?
2. Why might a famous scientist be slow to believe that an unknown carpenter could solve a great problem?

PROJECT: CAN A PENDULUM KEEP TIME AT SEA?

In 1714 the best clocks in the world were pendulum clocks. You will build a simple pendulum, see how steadily it swings on dry land, and then put it to sea on a rocking “ship” to find out why the Longitude Prize was so hard to win.

You will need

- String, about 4 feet (1.2 m) long
- A heavy metal washer, large nut or fishing weight
- Masking tape and a yardstick
- A timer or a phone stopwatch
- A sturdy box or a stool to hang the pendulum from, and a wagon, sled or large tray to carry it
- A helper

Steps

1. Tie the washer to one end of the string. Measure 39 inches (about 99 cm) from the center of the washer up the string and mark that spot. A pendulum this long takes about one second for each swing.
2. Tape the string at the mark to the edge of a table or a doorframe so it hangs freely.
3. Pull the washer a few inches to one side and let go. Count the swings (one swing is from one side to the other) for 30 seconds while your helper watches the timer. Do this three times and write the counts in your notebook.
4. Now go to sea. Tie or tape the pendulum to the edge of a box or stool set inside a wagon or on a big tray. Start it swinging, then have your helper rock and bump the wagon gently, like a ship in waves, while you count for 30 seconds. Do this three times.
5. Shorten the string to 20 inches (about 50 cm) and count again on dry land. What changed?
6. Make a table: Dry land, At sea, Short string. Compare the counts.
7. Write two sentences: Why would a pendulum clock lose or gain time on a ship? Why does it matter that heat makes a metal pendulum rod a little longer?

Tips

- Keep the swings small. Big swings are less even.
- If the counts on dry land are almost the same each time, your pendulum is a good “clock.” The question is whether it stays good at sea.

Check your work

- I counted swings on dry land and at sea and wrote them in a table.
- I can explain why a pendulum clock could not find longitude on a rolling ship.
- I can explain why the length of a pendulum changes how fast it swings.

MAP NOTEBOOK

1. Draw a globe with the equator, two parallels of latitude and three meridians. Label which lines tell latitude and which tell longitude.
2. Make a chart of the three prizes of 1714: £20,000 for $\frac{1}{2}^\circ$, £15,000 for $\frac{2}{3}^\circ$, £10,000 for 1° . Next to each, write the distance in nautical miles at the equator.
3. Draw three small pictures of the ideas Parliament heard about: a clock, Jupiter with its moons, and the moon beside a star.

From history. The Board of Longitude met for more than a hundred years, until 1828. It never handed one person the full £20,000 in a single award, but it gave many smaller rewards to people who helped navigation. One went to the widow of the German astronomer Tobias Mayer, whose careful tables of the moon made the lunar distance method practical; she received £3,000 in 1765.

WORKED EXAMPLES

Example 1. The top prize asked for longitude within half a degree. At the equator, how far is that in nautical miles, and about how far in ordinary miles?

(Use the map or drawing “Half a degree at the equator is the inner circle, 30 nautical miles.” shown earlier in this lesson.)

1. One degree is 60 nautical miles, so half a degree is $60 \div 2 = 30$ nautical miles.
2. One nautical mile is about 1.15 ordinary miles, so $30 \times 1.15 = 34.5$ miles.
3. Round to about 35 miles (about 56 km).

Answer: 30 nautical miles, about 35 miles (56 km).

Example 2. A clock is carried on a 42-day voyage to the West Indies. To win the £20,000 prize, about how much may it drift in all, and about how much per day?

1. The earth turns 15° in 60 minutes, so it turns 1° in $60 \div 15 = 4$ minutes.
2. Half a degree takes half as long: $4 \div 2 = 2$ minutes. So the clock may be off by no more than 2 minutes (120 seconds) at the end.
3. Spread over 42 days: $120 \div 42$ is a little less than 3 seconds a day.

Answer: About 2 minutes in all, a little less than 3 seconds a day.

PRACTICE

1. **EASY** What did the Longitude Act of 1714 promise, and how did a method have to prove itself?
2. **EASY** Which was easier for a sailor in 1714 to find, latitude or longitude? Why?

3. **EASY** How many nautical miles are in one degree of latitude? How many in one minute of latitude?
4. **MEDIUM** How many nautical miles is two-thirds of a degree at the equator? Which prize was it worth?
5. **MEDIUM** The earth turns all the way around (360°) in 24 hours. How many degrees does it turn in 1 hour? In 4 minutes?
6. **MEDIUM** A navigator's clock is 4 minutes wrong. How far wrong is his longitude in degrees? Near the equator, about how many nautical miles and ordinary miles is that?
7. **HARD** To win the £10,000 prize (one degree), how many minutes in all could a clock drift on a six-week voyage? About how many seconds is that per week?
8. **CHALLENGE** The prize was open to anyone, not only to famous scientists. Write two or three sentences on why that was wise.

COMMON MISTAKES

- Mixing up latitude and longitude. Latitude tells north or south; longitude tells east or west.
- Thinking a degree of longitude is always 69 miles. That is true only at the equator. Meridians come together at the poles, so a degree of longitude gets shorter as you go north or south.
- Mixing up minutes of time and minutes of arc. Four minutes of clock time equal one degree (60 minutes of arc) of longitude.

Make it a game · Latitude or Longitude?. A parent calls out a clue, such as “the North Star,” “a clock from home,” “east of Greenwich,” “the equator” or “15 degrees every hour.” Shout “Latitude!” or “Longitude!” and give one reason. One point for the right word, one more for a good reason. First to ten points wins the £20,000 (in play money).

Scripture. “They that go down to the sea in ships, that do business in great waters; These see the works of the LORD, and his wonders in the deep.” (Psalm 107:23-24, KJV)

Sailors saw God's wonders, and they also faced real dangers. Caring for their lives by finding better ways to navigate is a way of loving our neighbor.

Practice answers

1. Up to £20,000 to anyone who could find longitude at sea within half a degree (£15,000 for two-thirds of a degree, £10,000 for one degree). It had to be tested on a voyage from Great Britain to the West Indies.
2. Latitude. The height of the North Star or the noon sun tells latitude directly. Longitude has no natural starting line, and finding it needs the exact time at home and at the ship.
3. 60 nautical miles in a degree; 1 nautical mile in a minute.
4. $\frac{2}{3} \times 60 = 40$ nautical miles; the £15,000 prize.
5. $360 \div 24 = 15^\circ$ in an hour; 1° in 4 minutes.
6. 1° , which is 60 nautical miles, about 69 miles (111 km).

7. 1° is 4 minutes of time, so 4 minutes (240 seconds) in all. $240 \div 6 = 40$ seconds per week.
8. Answers will vary. A good answer says that no one knew where the answer would come from, that skill and hard work can be found in ordinary people, and that opening the prize to all gave the best chance of saving sailors' lives. (In fact the answer came from a country carpenter.)

3.2 JOHN HARRISON'S CLOCKS ★ ⚙️

OBJECTIVES

- Tell the story of John Harrison, the carpenter who built the sea clocks H1, H2, H3 and H4.
- Explain how Harrison solved the problems of a rolling ship and of heat and cold.
- Change a clock's error in seconds into an error in longitude and in nautical miles.

Warm-up. Hold a pocket watch, a wristwatch or a kitchen timer in your hand. Now picture a grandfather clock. Which one could you carry to sea in a storm? Gently rock a small toy or a cup of water on a tray. What happens to things that swing or slosh? Make a list of three things that could make a clock run fast or slow on a ship.

Watch. *A Detailed Study of H4 - John Harrison's Longitude Timekeeper Reconstruction*

(Barbara Darby, 2:57). <https://www.youtube.com/watch?v=UeEBa55S7MI>

With the big idea: look closely at the inside of H4, Harrison's watch-sized timekeeper, and compare it with the big brass H1 from the story.

Note: Captions were not available to check; preview it first. The video is about a modern copy of H4 built from 1997 to 2014, not about Harrison's life, and the description advertises a DVD. This shows a modern reconstruction, not Harrison's original H4.

Backup video. *John Harrison* (ClockmakerJeff, 4:08). <https://www.youtube.com/watch?v=xjNx0x8qCWc>

As review: watch for Harrison's sea clocks H1 to H4 and how each one kept better time on a moving ship. Note: Captions were not available to check; preview it first. The only details we could find were the title "John Harrison" and the channel name ClockmakerJeff.

KEY TERMS

chronometer

A very accurate clock or watch built to keep time at sea, so a navigator can find longitude.

balance

A wheel or bar in a clock that swings back and forth at a steady beat, like a pendulum that does not need gravity.

bimetallic strip

Two thin strips of different metals, such as brass and steel, joined together. Heat makes one grow more than the other, so the strip bends. Harrison used it to keep his clocks steady in heat and cold.

rate

How much a clock gains or loses each day. A clock with a steady, known rate can be corrected by arithmetic.

lignum vitae

A very hard, naturally oily tropical wood. Harrison used it in his wooden clocks because it needs no oil.

CORE IDEAS

The story. In 1736 a Navy ship, HMS *Orford*, was sailing home to England from Lisbon in Portugal. On board was a Yorkshire-born carpenter named John Harrison, and beside him, in a big box, ticked a strange brass machine about two feet tall. It was his first sea clock, now called **H1**. As they neared the English coast, the ship's master worked out their position the usual way and believed they were near a headland called the Start. Harrison checked his clock and said they were well to the west of that, near the Lizard in Cornwall. Harrison was right. A carpenter's clock had beaten an experienced navigator.

The carpenter. John Harrison was born in 1693 in Yorkshire and grew up in the village of Barrow upon Humber in Lincolnshire. Like his father he worked as a carpenter, and he taught himself mathematics and mechanics from borrowed books. As a young man he built clocks almost entirely of wood. For the moving parts he chose **lignum vitae**, a tropical wood so oily that it needs no oil, because oil in clocks of that day turned sticky and slowed them down. A clock he built for the stable at Brocklesby Park, a great house nearby, around 1722 is still running today. In 1730 Harrison went to London with plans for a sea clock. The astronomer Edmond Halley sent him to George Graham, the finest clockmaker in England, who was so impressed that he lent Harrison money to build it.

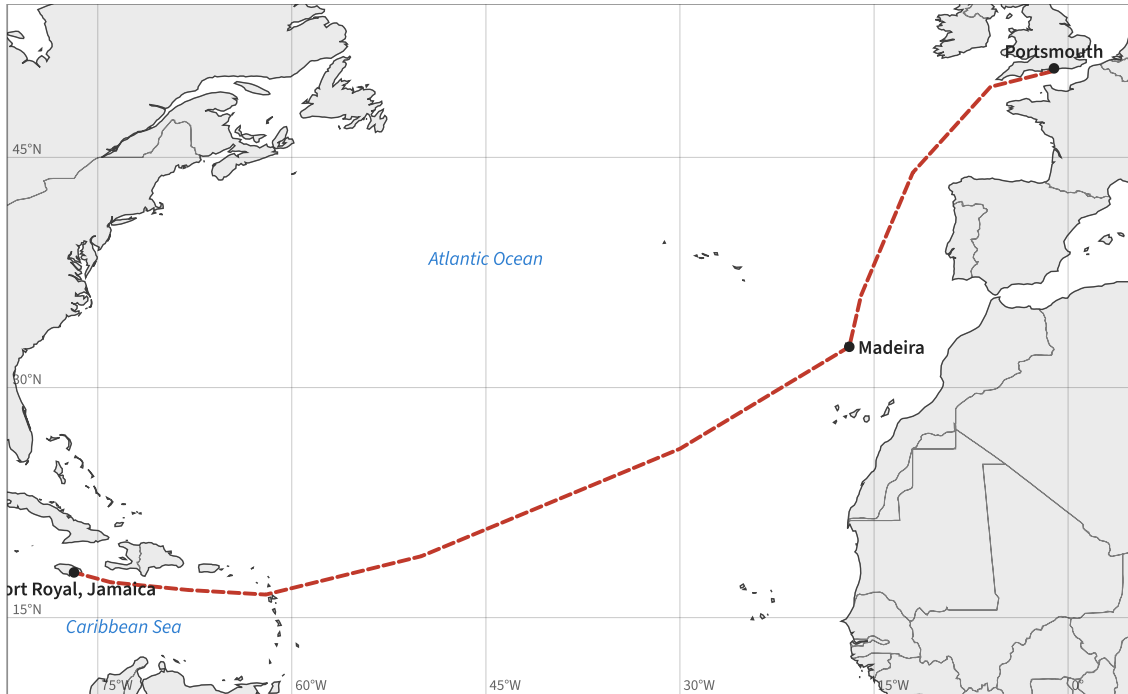
How it worked. A pendulum fails at sea because the ship's rocking pushes it. So Harrison used no pendulum at all. In H1 two heavy bars, linked by springs, swing in opposite directions, so a roll of the ship that speeds one up slows the other down. Heat was the second enemy: warm metal grows longer and springs grow weaker, so a clock slows down on a hot day. In H1 Harrison fought it with rods of brass and steel working against each other. His next clocks, H2 and H3, brought more inventions. H3 took him **nineteen years** (1740–1759). In it he used a **bimetallic strip**, the same idea that works inside many thermostats today, and a cage of little rollers that helped lead to the ball bearings in bicycles and cars.

The big surprise. While he labored on H3, Harrison noticed that a small watch with a fast-beating balance could be steadier than a big slow clock. So he built a watch. **H4**, finished in 1759 when he was sixty-six, is only about 5 inches (13 cm) across and weighs about 3 pounds. In November 1761 his son William carried it on HMS *Deptford* to Jamaica. When they arrived in January 1762, after allowing for its known steady rate, H4 was only about 5 seconds off. That was far better than the prize required. A second trial to Barbados in 1764 gave the same kind of result.

Honest judgment. Still the Board of Longitude would not pay the full prize. The Board wanted more than one wonderful watch made by one man; it wanted a method any ship could use, and it suspected H4's success might be luck. It made Harrison explain H4 to a panel of experts and have a copy made by another maker. Harrison felt cheated, and many people agreed with him. In 1765 he received £10,000. In 1772 King George III himself tested

Harrison's next watch, H5, at his own observatory, and in 1773 Parliament awarded Harrison £8,750 more. He died in 1776, on his eighty-third birthday.

Technology overcoming geography. Harrison did not move a mountain or dig a canal. He built a small machine that let a ship carry home's time across the whole ocean. With it the sea was no longer a blank: every ship could know its place.



The first sea trial of H4, on HMS Deptford: Portsmouth to Jamaica, November 1761 to January 1762, with a stop at Madeira.

PICTURE STUDY



H4 Marine Timekeeper, John Harrison, 1759 · Silver case, with a movement of brass and steel and jeweled bearings · Royal Observatory, Greenwich (Royal Museums Greenwich)

H4 looks like an oversized pocket watch, but it changed the history of the sea. John Harrison finished it in 1759 after nearly thirty years of work on sea clocks. Inside, its balance beats five times a second, and tiny polished jewels, including diamonds, take the wear where parts rub. The back plate is decorated with fine engraving, as if Harrison knew he had made something precious.

Today H4 sits in a glass case at the Royal Observatory in Greenwich, a few steps from the prime meridian, near the three great clocks that came before it. It is kept still now, to protect it.

Look closely

- Look at the dial. How many hands can you find? Why would a navigator need to read seconds?
- Look at the size of H4 and imagine H1, about two feet tall, standing beside it. What did Harrison gain by making his timekeeper small?
- Inside the case, Harrison covered the back plate with fine engraving that almost no one would see. Why would a carpenter who cared about plain hard work also make something beautiful?
- Someone had to wind H4 every day at sea. What would happen if they forgot?

Talk about it

1. H4 is called a “marine timekeeper.” What does each of those two words tell you?

2. Why might the Board of Longitude worry that one beautiful, handmade watch was not yet a method every ship could use?
3. What does H4 tell you about the man who made it?

PROJECT: PUT A WATCH ON TRIAL

The Board of Longitude did not trust promises; it tested. You will put a watch or clock in your house on trial for one week, just as H4 was tried at sea, and find its **rate**: how many seconds it gains or loses each day.

You will need

- A watch or clock with a seconds hand or a seconds display (not a phone or computer, which set themselves automatically)
- Access to an official time source: the U.S. time website time.gov, or a radio-controlled clock
- Notebook and pencil

Steps

1. Make a trial log with four columns: Day, Official time, My watch, Difference (seconds fast or slow).
2. On Day 0, set your watch as exactly as you can to the official time. Write down the difference (it may be 0 or 1 second).
3. Every day at about the same hour, compare your watch with the official time at the moment the official seconds reach :00. Write the difference. Use + for fast and – for slow.
4. Do this for 7 days. Do not reset the watch during the trial.
5. Find the total change from Day 0 to Day 7. Divide by 7 to find the daily rate.
6. Use the rate: if your watch went to sea, how many seconds off would it be after 42 days? Divide that by 4 to find how many minutes of longitude that would be.
7. Write: Would your watch have won £20,000 (2 minutes or less after six weeks), £10,000, or nothing?

Tips

- A cheap quartz watch is often very good; it may gain or lose less than a second a day. An old wind-up clock may be off by many seconds.
- A steady rate is what matters most. A watch that loses exactly 2 seconds every day is more useful to a navigator than one that is sometimes fast and sometimes slow.

Check your work

- I kept a trial log for seven days.
- I found my watch's daily rate.
- I can explain why a steady rate can be corrected by arithmetic.

MAP NOTEBOOK

1. Draw a timeline from 1693 to 1776 and mark Harrison's birth, the Brocklesby Park clock (about 1722), H1 (1735), H3 finished and H4 finished (1759), the Jamaica trial (1761–1762), the reward from Parliament (1773) and his death (1776).
2. Draw H1 and H4 side by side, with H1 about five times taller, and label each.
3. Draw a bimetallic strip: a brass strip and a steel strip side by side. Draw it again bent into a curve when heated, with the brass on the outside of the curve, because brass grows more.

From history. After Harrison's death his clocks were nearly forgotten, and H1 to H3 sat dirty and stopped at Greenwich. In 1920 a Navy officer named Rupert Gould asked permission to clean them. He spent years repairing them, often without pay, and got them running again. Today H1, H2, H3 and H4 are displayed together at the Royal Observatory in Greenwich.

WORKED EXAMPLES

Example 1. Harrison was born in 1693. He finished H1 in 1735 and H4 in 1759. How old was he when he finished each, and how many years passed from H1 to H4?

1. H1: $1735 - 1693 = 42$ years old.
2. H4: $1759 - 1693 = 66$ years old.
3. From H1 to H4: $1759 - 1735 = 24$ years.

Answer: About 42 for H1 and about 66 for H4; 24 years passed between them.

Example 2. When H4 reached Jamaica in 1762 it was only about 5 seconds off. How much error in longitude is that, and about how many nautical miles?

(Use the map or drawing "H4's voyage to Jamaica, 1761–1762." shown earlier in this lesson.)

1. The earth turns 1° (60 minutes of arc) in 4 minutes of time, which is 240 seconds. So 4 seconds of time = 1 minute of arc.
2. $5 \text{ seconds} \div 4 = 1\frac{1}{4}$ minutes of longitude.
3. At the equator 1 minute of longitude is 1 nautical mile, so the error is about $1\frac{1}{4}$ nautical miles (a little less near Jamaica, where the meridians are slightly closer together).
4. The top prize allowed 30 nautical miles. H4 was more than 20 times better than that.

Answer: About $1\frac{1}{4}$ minutes of longitude, roughly $1\frac{1}{4}$ nautical miles (about $1\frac{1}{2}$ ordinary miles).

PRACTICE

1. **EASY** What was John Harrison's trade, and in what English county did he grow up?
2. **EASY** Why did Harrison use lignum vitae wood in his early clocks?
3. **EASY** Name two enemies of good timekeeping at sea that Harrison had to defeat.
4. **MEDIUM** Harrison worked on H3 from 1740 to 1759. How many years is that? How old was he when he started it?
5. **MEDIUM** HMS Deptford left Portsmouth on November 18, 1761, and reached Jamaica on January 19, 1762. How many days was the voyage? (November has 30 days and December has 31.)
6. **MEDIUM** On the second trial, to Barbados in 1764, H4's error was less than 40 seconds. How many minutes of longitude is 40 seconds of time? About how many nautical miles at the equator?
7. **HARD** A sea watch loses exactly 2 seconds every day. After 50 days, how far behind is it? What should the navigator do before working out longitude?
8. **CHALLENGE** Was the Board of Longitude fair to Harrison? Write three or four sentences that give one reason on each side.

COMMON MISTAKES

- Thinking Harrison invented the idea of using a clock for longitude. The idea was old; Harrison was the first to build a clock good enough.
- Picturing H4 as a big clock. H1 to H3 were large, but H4 is a watch about 5 inches across.
- Thinking Harrison received the £20,000 all at once. He was paid in parts, over many years, and the last money came from Parliament in 1773, not from the Board.

Make it a game • Clockmaker's Timeline. Write these on cards: Harrison born, Brocklesby Park clock, H1 sails to Lisbon, H3 finished, H4 sails to Jamaica, the King tests H5, Harrison dies. Shuffle them. Race a parent or sibling to lay them in order and say a date for each. Score a point for each card in the right place and a bonus point for each correct year.

Scripture. "Seest thou a man diligent in his business? he shall stand before kings; he shall not stand before mean men." (Proverbs 22:29, KJV)

A village carpenter who worked faithfully for more than forty years ended by having his watch tested by King George III. Patient, careful work is never small in God's sight.

Practice answers

1. He was a carpenter (and a self-taught clockmaker). He grew up in Barrow upon Humber, Lincolnshire, after being born in Yorkshire.
2. It is hard and naturally oily, so the parts did not need oil, which in those days turned sticky and spoiled a clock's timekeeping.

3. Any two: the rolling and pitching of the ship; heat and cold; damp and salt air; worn or sticky (oiled) parts.
4. $1759 - 1740 = 19$ years. $1740 - 1693 = 47$ years old.
5. 12 days left in November + 31 in December + 19 in January = 62 days.
6. $40 \div 4 = 10$ minutes of longitude, about 10 nautical miles. (The prize allowed 30.)
7. $2 \times 50 = 100$ seconds, which is 1 minute 40 seconds slow. He adds 1 minute 40 seconds to the watch's reading. A steady, known rate can be corrected.
8. Answers will vary. For Harrison: H4 did better than the Act required, yet he waited years and never received the prize as the Act described it. For the Board: it had to be sure the result was not luck and that the watch could be copied by other makers, because a single watch could not guide the whole Navy. A good answer weighs both.

3.3 TIME TELLS PLACE

OBJECTIVES

- Explain why each hour of time difference equals 15 degrees of longitude, and each 4 minutes equals 1 degree.
- Find a ship's longitude from the Greenwich time of its local noon.
- Read a map of time zones and longitude lines and explain why zones follow the meridians.

Warm-up. In a dim room, shine a flashlight or lamp on a globe from one side. Put a small sticker on your town. Slowly turn the globe from west to east (counterclockwise when you look down on the North Pole). Say “Noon!” when your sticker faces the lamp most directly. Now put a second sticker on London and turn again. Which city reaches noon first?

Watch. *When Did Time Zones Become a Thing? (Short Animated Documentary)* (History Matters, 3:20). <https://www.youtube.com/watch?v=PFRN9ZgbIAI>

With the big idea: watch how the railroads and the telegraph led to Greenwich time in Britain and to the railroads' Standard Time in America in 1883.

Note: Transcript checked. Ends with a list of the channel's Patreon supporters; stop it there.

Backup video. *Understanding Time Zones* (Mr Gedge's Geography Channel, 4:17).

<https://www.youtube.com/watch?v=X1DkiuaFCuA>

As review: watch a geography teacher explain why each 15 degrees of longitude makes one hour of time difference. Note: Captions were not available to check; preview it first.

KEY TERMS

local noon

The moment the sun is highest in the sky at a place. In most of the United States the sun is then due south and shadows are shortest and point due north.

local time

Time kept by the sun at one place, so that noon comes when the sun is highest there.

Greenwich time

The time at the prime meridian in Greenwich, England. A ship's chronometer was set to it before the voyage.

time zone

A wide band of the earth where everyone sets clocks to the same time, usually the local time of a meridian that is a multiple of 15°.

standard time

The shared clock time of a time zone, first adopted by railroads in the United States and Canada in 1883.

CORE IDEAS

The story. On Sunday, November 18, 1883, the clocks in many American towns struck noon twice. Until that day nearly every town kept its own **local time**, set by the sun. When it was noon in Chicago it was about 12:06 in Indianapolis and about 12:18 in Columbus, Ohio. The railroads used dozens of different times, and their timetables were a puzzle. So the railroads of the United States and Canada agreed to use a few **standard times**, one for each wide band of the country. In New York, when the sun said noon, the clocks were stopped and then started again about four minutes later, when it was noon by the new Eastern time: a “day of two noons.” The next year, in 1884, delegates from about two dozen nations met in Washington, D.C., and chose the meridian through Greenwich as the world’s prime meridian, 0° longitude.

How it works. God made the earth to turn steadily from west to east, once around (360°) every 24 hours. Divide, and you find the earth turns **15° every hour**. Divide again: 15° in 60 minutes is **1° every 4 minutes**. Because the earth turns toward the east, places to the east see the sun rise, climb and reach **local noon** first. A town 15° west of another has noon one hour later. A town 1° west has noon 4 minutes later. Time and place are tied together like two gears.

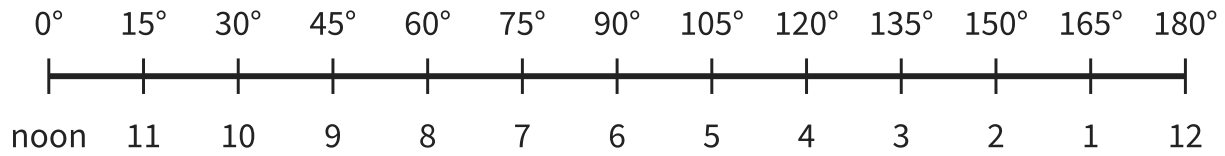
The navigator’s two clocks. This is why Harrison’s watch could find longitude. Before the voyage the chronometer was set to **Greenwich time** and never changed. At sea the navigator measured the sun with his quadrant to catch the moment of local noon, when the sun stood highest. Then he looked at the chronometer. Suppose it read 3:00 in the afternoon. Noon had already come to Greenwich three hours before, so the ship was three hours of turning to the west: $3 \times 15^\circ = 45^\circ$ west. If the chronometer had read 9:00 in the morning, the ship would be 45° east. Old navigators kept a rhyme: *Longitude east, Greenwich time least; longitude west, Greenwich time best*. In other words, if Greenwich time is later than your time, you are west.

On the map. Time zones follow the same rule. Each zone is about 15° wide, so its clocks are a whole hour different from the next. In the United States, Eastern time is the local time of the 75th meridian west, near Philadelphia. Central time belongs to 90° west, close to Memphis and New Orleans. Mountain time belongs to 105° west, which runs very near Denver. Pacific time belongs to 120° west, near Reno and Lake Tahoe. On a real map the zone borders zigzag, because people would rather have a whole state or city on one time than cut it in two. Halfway around the world from Greenwich, near 180°, runs the International Date Line, where the calendar changes by a day.

Technology overcoming geography. Three inventions came together in this story. Harrison’s chronometer carried Greenwich time across the ocean. The railroad carried travelers so fast that a few minutes of sun time between towns began to matter. And the telegraph sent exact time signals down the wires from observatories, so that a whole country

could set its clocks together. Distance had always made each town its own little world; now the turning of the earth became a single clock for everyone.

Longitude west of Greenwich



Sun time at each meridian when it is noon at Greenwich
(a.m. hours; 12 at 180° is midnight). Each 15° = 1 hour.

Each 15° west of Greenwich is one hour earlier by the sun. When it is noon at Greenwich, it is 7 a.m. at 75°W and midnight at 180°.



The four main U.S. time zones are each built around a meridian that is a multiple of 15°.

PICTURE STUDY



A Philosopher Lecturing on the Orrery, Joseph Wright of Derby, about 1766 · Oil on canvas · Derby Museum and Art Gallery, Derby, England

Joseph Wright lived in the town of Derby in the English Midlands in the same years that John Harrison was building his sea watches in London. He loved to paint people lit by a single light in the dark, and he loved the new science of his day. Here a lecturer shows a family and their friends an **orrery**, a clockwork model of the sun, the earth and the planets. A lamp stands in place of the sun, so the faces turned toward it glow, just as the side of the earth facing the sun has day.

An orrery shows exactly what this lesson is about: the earth turning and circling in perfect order, so steadily that a clock can follow it and a sailor can use it to find his place.

Look closely

- Find the light. You cannot see the lamp itself. How do you know where it is?
- Look at the children's faces. Which ones are lit brightly? What does that remind you of on the turning earth?
- Find the man writing in a notebook. Why would someone take notes at a lecture like this?
- Find the brass rings and the little balls on rods. Which might stand for the earth and the moon?

Talk about it

1. How does the lamp in the orrery help explain day and night, and why noon comes at different times in different places?

2. Why do you think Wright painted ordinary people, not kings or saints, gazing at a science model with wonder?

Safety first. Never look at the sun, even for a moment, and never look at it through anything. In this project you watch only the shadow on the ground.

PROJECT: FIND YOUR LONGITUDE FROM LOCAL NOON

Sailors with a chronometer found longitude by catching local noon. You have a chronometer too: any clock or phone that shows standard time. With a stick and its shadow you will catch your own local noon and work out how far west of Greenwich you live.

You will need

- A straight stick or dowel about 12 inches (30 cm) long, or a pencil stuck upright in a lump of clay
- A large piece of cardboard or poster board, and tape or rocks to hold it flat
- A small square or book corner to check that the stick is upright
- String and a pencil (to draw a circle), pebbles or coins, a marker
- A clock or phone showing the time to the minute
- A map or atlas that shows your town's longitude

Steps

1. Choose a sunny day. Lay the cardboard on flat ground in full sun and weigh it down. Stand the stick upright in the middle and check it with the square from two sides.
2. Begin at 11:30 a.m. standard time (12:30 p.m. if your clocks are on daylight saving time). Every 10 minutes, mark the tip of the shadow with a dot and write the time beside it. Continue for two hours.
3. Look at your dots. The shortest shadow came at about local noon, and it points due north. Write down that time.
4. For a better answer, use the circle trick. Tie a string to the stick, and draw a circle on the cardboard that the shadow tip crosses in the late morning. Write the time the tip touches the circle before noon and the time it touches the circle again after noon. Local noon is exactly halfway between those two times.
5. If your clocks are on daylight saving time, subtract 1 hour from your noon time to get standard time.
6. Find your time zone's meridian: Eastern 75°W, Central 90°W, Mountain 105°W, Pacific 120°W. Count the minutes between 12:00 and your local noon. Divide by 4 to get degrees. If your noon came after 12:00, add those degrees to your zone's meridian; if it came before 12:00, subtract them.
7. Compare your answer with your town's longitude in an atlas. Write both in your notebook. How close did you come?

Tips

- The sun is not a perfect clock: through the year it runs up to about 16 minutes fast or slow. Near April 15, June 13, September 1 and December 25 the difference is very small. On other dates a parent can look up the “equation of time” for the day (the NOAA Solar Calculator lists it). If the sun is fast, add those minutes to your noon time; if it is slow, subtract them.
- Every 4 minutes of error makes 1 degree of error. Missing noon by 8 minutes puts you 2° off, which is why Harrison’s seconds mattered so much.

Check your work

- I marked the shadow and found the time of local noon.
- I changed minutes into degrees and worked out my longitude.
- I compared my answer with the atlas and can explain the difference.

MAP NOTEBOOK

1. Copy the time strip: longitudes 0° to 180°W in steps of 15°, with the local time at each when it is noon at Greenwich.
2. Draw an outline of the United States and draw the meridians 75°W, 90°W, 105°W and 120°W. Write the time zone name beside each, and a star for where you live.
3. Write the navigator’s rhyme in your best handwriting and draw a ship and a clock beside it: “Longitude east, Greenwich time least; longitude west, Greenwich time best.”

From history. Not every nation was ready to count from Greenwich in 1884. At the meeting in Washington, France did not vote for Greenwich, and French maps went on counting longitude from the meridian of Paris for many years. Greenwich won in the end partly because most of the world’s ships already used British sea charts, which counted from Greenwich.

WORKED EXAMPLES

Example 1. At local noon on a ship in the Atlantic, the chronometer (set to Greenwich time) reads 3:00 p.m. What is the ship’s longitude?

(Use the map or drawing “Three hours earlier than Greenwich lands on 45°W.” shown earlier in this lesson.)

1. Greenwich time is later than the ship’s time (3:00 p.m. is after noon), so the ship is west of Greenwich (“Greenwich time best, longitude west”).
2. The difference is 3 hours.
3. Each hour is 15°: $3 \times 15^\circ = 45^\circ$.

Answer: 45° west.

Example 2. A ship is nearing North America. At local noon the chronometer reads 4:52 p.m. Greenwich time. What is the ship's longitude, and what big city is near that meridian?

(Use the map or drawing "73°W lies just east of the 75°W meridian of Eastern time." shown earlier in this lesson.)

1. Greenwich time is later, so the ship is west.
2. Split the difference into hours and minutes: 4 hours 52 minutes.
3. $4 \text{ hours} \times 15^\circ = 60^\circ$.
4. $52 \text{ minutes} \div 4 = 13^\circ$.
5. $60^\circ + 13^\circ = 73^\circ$.

Answer: 73° west, just east of New York City (about 74°W).

PRACTICE

1. **EASY** How many degrees does the earth turn in 1 hour? In 2 hours? In 4 minutes?
2. **EASY** What is local noon? Which way does a shadow point at local noon in the 48 connected states?
3. **EASY** Use the time strip. When it is noon at Greenwich, what is the sun time at 30°W? At 90°W?
(Use the map or drawing "Read down from each longitude to its time." shown earlier in this lesson.)
4. **MEDIUM** At local noon a ship's chronometer reads 2:00 p.m. Greenwich time. What is the longitude?
5. **MEDIUM** At local noon a ship in the Indian Ocean finds its chronometer reads 6:00 a.m. Greenwich time. What is the longitude?
6. **MEDIUM** Use the U.S. map. Denver lies almost exactly on 105°W. How many hours behind Greenwich is Mountain Standard Time? Which time zone is one hour ahead of it?
(Use the map or drawing "Find Denver on the 105°W meridian." shown earlier in this lesson.)
7. **HARD** At local noon a ship's chronometer reads 5:20 p.m. Greenwich time. Find the longitude.
8. **CHALLENGE** Philadelphia is near 75°W and Reno is near 120°W. How many degrees apart are they? How many hours apart are their local noons? Which sees noon first, and why?

COMMON MISTAKES

- Getting east and west backward. If Greenwich time is later than your local time, you are west; if it is earlier, you are east.
- Treating minutes of time like degrees. Divide minutes of time by 4 to get degrees; do not use them as degrees directly.
- Forgetting daylight saving time. In summer, most American clocks are set one hour ahead, so subtract an hour before working out longitude.

Make it a game · Noon Around the World. In a dim room one player shines a lamp on a globe. Put sticky notes on five cities, such as London, New York, Chicago, Denver and Honolulu. Another player slowly turns the globe from west to east. The others shout each city's name as it reaches noon (faces the lamp most directly). Then say how many hours after London each city had its noon. One point for each correct order and one for each correct hour count.

Scripture. "And God said, Let there be lights in the firmament of the heaven to divide the day from the night; and let them be for signs, and for seasons, and for days, and years:" (Genesis 1:14, KJV)

God made the sun and stars for signs and for days. Their faithful, orderly motion is what lets a shadow on the ground, or a clock at sea, tell us where we are.

Practice answers

1. 15° ; 30° ; 1° .
2. The moment the sun is highest in the sky at that place. The shadow is shortest and points due north.
3. 10 a.m. at 30°W ; 6 a.m. at 90°W .
4. $2 \text{ hours} \times 15^\circ = 30^\circ$; Greenwich is later, so 30° west.
5. $6 \text{ hours} \times 15^\circ = 90^\circ$; Greenwich time is earlier ("least"), so 90° east.
6. $105 \div 15 = 7$ hours behind Greenwich. Central time (90°W) is one hour ahead.
7. $5 \text{ hours} \times 15^\circ = 75^\circ$; $20 \text{ minutes} \div 4 = 5^\circ$; $75^\circ + 5^\circ = 80^\circ$ west.
8. $120 - 75 = 45^\circ$, which is $45 \div 15 = 3$ hours. Philadelphia sees noon first, because the earth turns from west to east and so carries the eastern city toward the sun first.

3.4 COOK TESTS THE CHRONOMETER ⚙

OBJECTIVES

- Tell how Captain James Cook carried K1, Larcum Kendall's copy of H4, on his second voyage (1772–1775).
- Explain how a navigator used a chronometer's rate and noon sightings to fix longitude around the world.
- Work out the longitudes of real places on Cook's route and plot them on a world map.

Warm-up. Set a kitchen timer or a phone stopwatch running and put it in a closed box. Every few minutes during the lesson, open the box, read the time aloud and close it again. Why would a ship keep its most precious clock locked in a box? Who should hold the key? Talk about it before you read.

Watch. *Larcum Kendall 'K1' - Captain Cook's historic chronometer watch at Greenwich - With the BHI* (British Horological Institute, 27:22). <https://www.youtube.com/watch?v=Xe0GXNf1Ilc>

After the story: watch the first few minutes to see the real K1 watch that rode on the Resolution taken apart, and look for the tiny parts that kept it accurate at sea.

Note: Captions were not available to check; preview it first. This is a long (27-minute) technical talk for watch experts, so watching only the opening section is enough for most students. The video is about how the K1 watch was built and repaired, not about Cook's voyage itself.

KEY TERMS

K1

The first copy of Harrison's H4, made by the London watchmaker Larcum Kendall and finished in 1769. Cook carried it on his second and third voyages.

Antarctic Circle

The parallel of latitude about $66\frac{1}{2}^\circ$ south. South of it the sun stays up all day for at least one day each summer.

lunar distance

The angle between the moon and a star or the sun, measured with an instrument and used with printed tables to find Greenwich time at sea.

Nautical Almanac

A yearly book of tables of the sun, moon and stars for navigators, first published in Britain for the year 1767 under Nevil Maskelyne, the Astronomer Royal.

position fix

A ship's place worked out from measurements, given as latitude and longitude.

CORE IDEAS

The story. On July 13, 1772, two ships sailed out of Plymouth, England: HMS *Resolution*, commanded by Captain James Cook, and HMS *Adventure*, under Tobias Furneaux. Their orders were to search the far southern ocean for a great southern continent that many mapmakers believed must exist. On board the *Resolution*, kept in a locked box and wound every day, ticked a silver watch called **K1**. The London watchmaker Larcum Kendall had built it as an exact copy of Harrison's H4, finishing it in 1769. The Board of Longitude wanted to know whether a copy could do what the original had done, not for six weeks but for three years, through tropical heat and polar cold.

How they figured it out. The Board sent an astronomer, William Wales, to sail with Cook and keep the watches. Wales and the officers checked K1 against the stars and the moon, using the **lunar distance** method and the new **Nautical Almanac**. Whenever they reached a harbor whose longitude was already well known, such as Cape Town, they compared K1 with the true local time and learned its **rate**: how many seconds it gained each day. Out at sea the navigator measured the sun to find local time, read K1 for Greenwich time, corrected for the rate and turned the difference into degrees, 15° for every hour. On his first voyage (1768–1771) Cook had depended on the lunar method alone, which took hours of arithmetic. Now a few minutes with the watch could give a **position fix**.

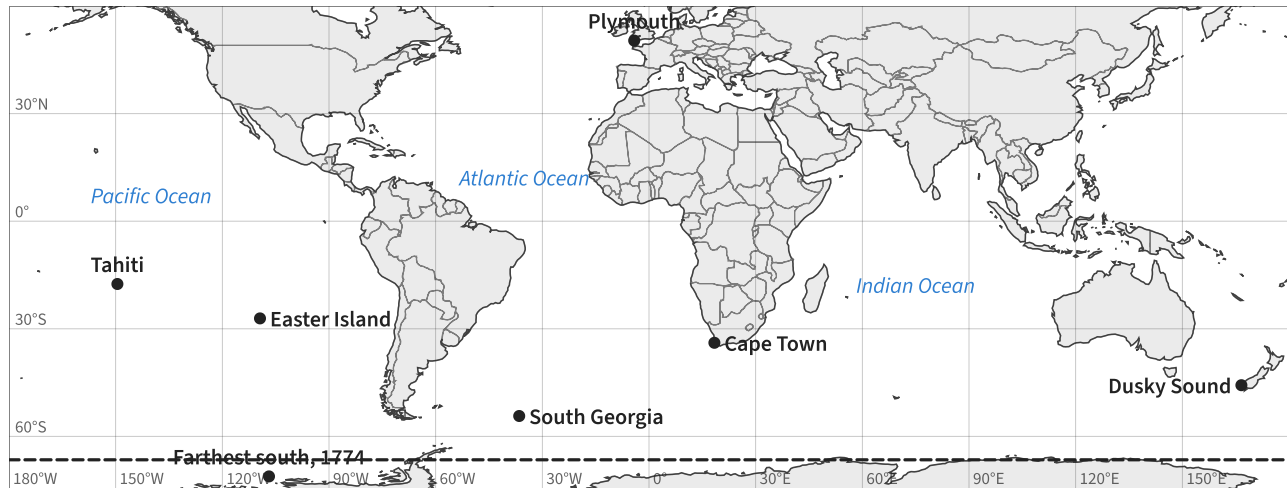
The voyage. From Cape Town, Cook turned south into fog and ice. On January 17, 1773, the *Resolution* and *Adventure* became the first ships known to cross the **Antarctic Circle**. A year later, on January 30, 1774, the *Resolution* reached $71^\circ 10'$ south before a wall of ice stopped her. Between the icy sweeps Cook rested his men in New Zealand and Tahiti and charted Easter Island, Tonga, the New Hebrides and New Caledonia. Then he crossed the Pacific to Cape Horn, found the cold island of South Georgia, and came home on July 30, 1775. He had circled the globe far to the south and shown that no rich southern continent lay in the temperate seas; if land existed, it lay buried in ice near the Pole. Cook's meetings with the peoples of the Pacific, both friendly and tragic, are part of the story of Unit 5.

The verdict. Through all that heat and cold, K1 kept a steady rate. In his journal Cook praised the watch warmly, calling it a trusty friend and a faithful guide through every kind of climate, and he asked to take it again on his third voyage. The watches made by another maker, John Arnold, for the *Adventure* did far less well. John Harrison was still alive when Cook came home, and the voyage settled the old question: a well-made copy of H4 could find longitude anywhere on earth.

On the map. Because of K1, the islands Cook charted were placed in the right longitude, so later ships could find them again. Chronometers were costly at first, so for many years navigators used them together with lunar distances. As makers such as John Arnold and Thomas Earnshaw learned to build good chronometers more cheaply, more ships carried them, and by the middle of the 1800s a chronometer was part of a well-found ship's gear.

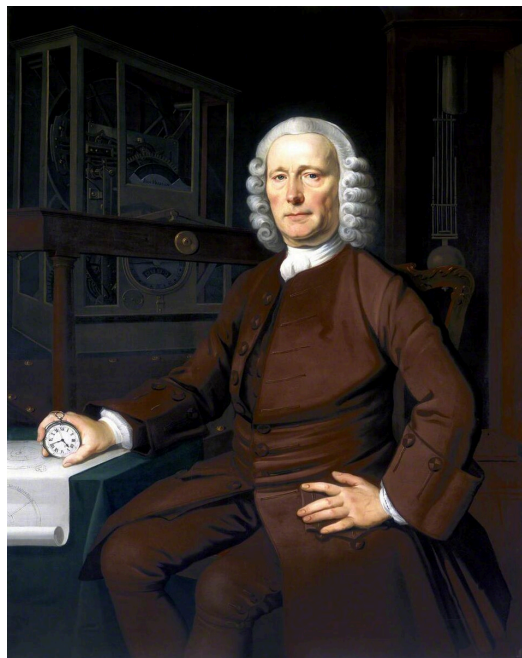
Technology overcoming geography. The Pacific is the widest ocean on earth, and its islands are tiny specks. A small watch in a locked box turned that vast space into a map that

sailors could trust.



Some of the places on Cook's second voyage, 1772-1775. The dashed line is the Antarctic Circle, about $66\frac{1}{2}^{\circ}\text{S}$.

PICTURE STUDY



Portrait of John Harrison, Thomas King, about 1767 · Oil on canvas · Science Museum, London

Thomas King painted John Harrison in his seventies, in the very years when Larcum Kendall was copying H4 to prove it could be made again. Harrison had been paid half the prize and was still fighting for the rest. He sits calmly, like a man who knows his work is good. Behind him stands one of his great sea clocks, which is usually identified as H3.

A few years after this portrait was painted, K1, the copy of H4, was crossing the Antarctic Circle with Captain Cook. The old carpenter's idea was being tested farther from home than any clock had ever gone.

Look closely

- Look at Harrison's face and hands. Is this a nobleman, or a man who has worked with his hands all his life? What clues do you see?
- Find the big brass clock behind him. What does the painter tell us by placing it there?
- Look at his clothes. Are they the clothes of a rich lord or of a plain, respectable working man?
- Find the brightest part of the picture. Where does the painter want your eye to go first?

Talk about it

1. Harrison never sailed with Cook. How could his work still be "on the voyage"?
2. If you could ask Harrison one question about his fifty years of work, what would it be?

PROJECT: PLOT COOK'S VOYAGE BY THE WATCH

You are William Wales, the astronomer on the *Resolution*. The log below gives the latitude of six places and the Greenwich time on the watch at each place's local noon. Work out each longitude and plot Cook's second voyage on your own map.

You will need

- A printed outline map of the world with latitude and longitude lines (free outline maps are easy to find and print)
- Pencil, colored pencils and a ruler
- Notebook for your calculations
- Your own longitude from Lesson 3.3

Steps

1. Copy this log into your notebook. Plymouth, latitude 50°N, watch reads 12:16 p.m. Cape Town, 34°S, 10:48 a.m. Dusky Sound, New Zealand, 46°S, 12:52 a.m. (52 minutes after midnight, so Greenwich is 11 hours 8 minutes earlier). Tahiti, 17½°S, 10:00 p.m. Easter Island, 27°S, 7:16 p.m. South Georgia, 54°S, 2:24 p.m.
2. For each place, find the difference between the watch time and noon. If the watch reads after noon, the place is west; if before noon, it is east.
3. Change the difference into degrees: hours × 15, plus minutes ÷ 4. Write each longitude with E or W.
4. Plot each place on your map with a dot and a label.
5. Draw the Antarctic Circle at 66½°S in blue. Mark Cook's farthest south, 71°S near 107°W, with a star.
6. Connect the places in the order Cook visited them: Plymouth, Cape Town, south to the ice, Dusky Sound, Tahiti, the farthest south, Easter Island, South Georgia, back to Cape Town and home to England. Use a red line, and remember the route may run off one edge of the map and come back on the other.

7. Add your own home and its longitude from Lesson 3.3. Write: How many degrees and how many hours of time lie between my home and Tahiti?

Tips

- Answers to check yourself: Plymouth 4°W, Cape Town 18°E, Dusky Sound 167°E, Tahiti 150°W, Easter Island 109°W, South Georgia 36°W.
- A ship in the South Seas is far from Greenwich, so the watch can read evening or even past midnight at the ship's noon. That is not a mistake; it is the whole point.

Check your work

- I worked out six longitudes from watch times.
- I plotted the places and drew the route in order.
- I can explain how K1 helped Cook put islands in the right place on the map.

MAP NOTEBOOK

1. Draw K1 in its locked box, with three keys beside it. Write one sentence on why the watch was guarded so carefully.
2. Draw a cross-section of the southern earth showing the equator, the Tropic of Capricorn, the Antarctic Circle and Cook's farthest south, 71°10'S.
3. Make a two-column chart: "Lunar distance" and "Chronometer." Write two good points and one weak point for each.

From history. Larcum Kendall later built two simpler and cheaper watches, now called K2 and K3. K2 sailed on HMS *Bounty* under William Bligh, and after the famous mutiny of 1789 the mutineers carried it off to lonely Pitcairn Island. Years later the captain of an American ship that found the mutineers' settlement was given the watch, and today it is back in Greenwich with K1.

WORKED EXAMPLES

Example 1. At Cape Town, at local noon, K1 (corrected for its rate) read 10:48 a.m. Greenwich time. What is Cape Town's longitude?

(Use the map or drawing "Cape Town lies about 18° east of Greenwich." shown earlier in this lesson.)

1. Greenwich time is earlier than the local noon (10:48 a.m. is before 12:00), so Cape Town is east of Greenwich ("Greenwich time least, longitude east").
2. The difference is $12:00 - 10:48 = 1 \text{ hour } 12 \text{ minutes}$.
3. $1 \text{ hour} \times 15^\circ = 15^\circ$. $12 \text{ minutes} \div 4 = 3^\circ$.
4. $15^\circ + 3^\circ = 18^\circ$.

Answer: About 18° east.

Example 2. At Matavai Bay, Tahiti, at local noon, K1 read 10:00 p.m. Greenwich time. What is the longitude? How far is that, in degrees, from Cape Town at 18°E?

(Use the map or drawing “Tahiti lies near 150°W, in the middle of the South Pacific.” shown earlier in this lesson.)

1. Greenwich time is later (10:00 p.m. is after noon), so Tahiti is west.
2. The difference is 10 hours. $10 \times 15^\circ = 150^\circ$. Tahiti is about 150°W.
3. To go from 18°E to 150°W across the prime meridian, add the two: $18^\circ + 150^\circ = 168^\circ$.

Answer: About 150° west, which is 168° of longitude from Cape Town (going west across Greenwich).

PRACTICE

1. **EASY** Name Cook’s two ships on his second voyage and give the years of the voyage.
2. **EASY** What was K1? Who made it, and why did the Board of Longitude want it tested?
3. **EASY** What important line of latitude did Cook’s ships cross on January 17, 1773, and why was it a first?
4. **MEDIUM** The voyage began on July 13, 1772, and ended on July 30, 1775. How long was it?
5. **MEDIUM** At Easter Island, at local noon, the watch read 7:16 p.m. Greenwich time. Find the longitude.
(Use the map or drawing “Check your answer against Easter Island on the map.” shown earlier in this lesson.)
6. **MEDIUM** Take the Antarctic Circle as 66°30’S. Cook’s farthest south was 71°10’S. How many degrees and minutes farther south did he go? How many nautical miles is that?
7. **HARD** Suppose a watch gains 4 seconds every day, and a careless navigator forgets to correct for it for 30 days. How far off is the watch? How large is the longitude error, and about how many nautical miles is that near the equator?
8. **CHALLENGE** Even after Cook’s voyage, navigators kept using lunar distances for many years. Give two reasons why, in complete sentences.

COMMON MISTAKES

- Thinking Cook carried H4 itself. Harrison’s H4 stayed in England; Cook carried K1, Kendall’s copy.
- Thinking chronometers replaced the lunar method overnight. For decades navigators used both, each checking the other.
- Forgetting the rate. A good chronometer is not perfect; it gains or loses a steady amount each day, and the navigator must correct for it.

Make it a game · Where Is the Ship? One player secretly picks a port on a world map and gives two clues: its latitude, and the Greenwich time on the watch at its local noon (for example, “34°S, 10:48 a.m.”). The others work out the longitude, then race to put a finger on the port. First to the right place scores a point. Take turns being the navigator who gives the clues.

Scripture. “If I take the wings of the morning, and dwell in the uttermost parts of the sea; Even there shall thy hand lead me, and thy right hand shall hold me.” (Psalm 139:9–10, KJV)

Cook’s men sailed to the uttermost parts of the sea, among ice that no ship had seen. A good watch showed them where they were, but the psalm reminds us that no one is ever lost to God.

Practice answers

1. HMS Resolution and HMS Adventure, 1772–1775.
2. K1 was a copy of Harrison’s H4 made by Larcum Kendall (finished 1769). The Board wanted to prove that H4 could be copied by another maker and would keep good time on a long voyage.
3. The Antarctic Circle (about 66½°S). They were the first ships known to cross it.
4. 3 years and 17 days.
5. $7 \text{ hours} \times 15^\circ = 105^\circ$; $16 \text{ minutes} \div 4 = 4^\circ$; $105^\circ + 4^\circ = 109^\circ$ west.
6. $71^\circ 10' - 66^\circ 30' = 4^\circ 40'$. That is $4 \times 60 + 40 = 280$ minutes of latitude, so 280 nautical miles (about 320 miles).
7. $4 \times 30 = 120$ seconds = 2 minutes. 2 minutes of time is half a degree (30 minutes of arc), about 30 nautical miles. Correcting for the known rate removes the error.
8. Chronometers were very expensive and few makers could build them, so most ships could not have one at first. A lunar distance also gave a check: if a chronometer stopped or went wrong, the navigator could still find Greenwich time from the moon and stars.

UNIT 3 REVIEW

Answer each question. Show your work for calculations and use complete sentences for explanations. Each problem is worth 5 points. The review is worth 50 points.

1. (5 pts) What did the Longitude Act of 1714 offer, and how did a method have to be tested?
2. (5 pts) Why was longitude so much harder to find at sea than latitude? Use the word “time” in your answer.
3. (5 pts) At the equator, how many nautical miles is half a degree of longitude? About how many ordinary miles? How many minutes of clock time is it?
4. (5 pts) Who was John Harrison? Name two problems of keeping time at sea and tell how he solved one of them.
5. (5 pts) H4 arrived in Jamaica in 1762 only about 5 seconds off. How many minutes of longitude is that? Was it within the £20,000 limit?
6. (5 pts) At local noon a ship’s chronometer, set to Greenwich time, reads 4:00 p.m. What is the ship’s longitude?
7. (5 pts) At local noon a ship’s chronometer reads 8:40 a.m. Greenwich time. What is the longitude?
8. (5 pts) Map reading: on the time zone map, Memphis lies near 90°W and Reno near 120°W. How many hours apart are their time zones? When it is 12:00 noon standard time in Memphis, what standard time is it in Reno?
9. (5 pts) What was K1? On which voyage was it tested, and what did the test prove?
10. (5 pts) Cook reached a cold island at about 54°S. At its local noon the watch read 2:24 p.m. Greenwich time. Find the longitude and name the island from the map of Cook’s voyage.

UNIT PROJECT: MY LONGITUDE LOGBOOK

Make a navigator’s logbook that tells the story of the longitude problem and proves you can solve it. Include: your pendulum test from Lesson 3.1, your one-week watch trial and its daily rate (3.2), your shadow-stick record with the time of local noon and the longitude you worked out, compared with an atlas (3.3), and your plotted map of Cook’s second voyage (3.4). Add a hand-drawn map of the United States (or your own region) showing the meridians 75°W, 90°W, 105°W and 120°W, the four time zones and a star for your home.

End with a short paragraph, written as if to John Harrison, explaining in your own words why “time tells place” and how his watch helped sailors.

- **Accuracy:** Longitudes, time differences and the watch rate are worked correctly, with east and west given; the home longitude is within a few degrees of the atlas.
- **Records:** The pendulum test, watch trial and shadow-stick record are complete, dated and neatly kept.

- **Maps:** The time-zone map and Cook's voyage map are clearly labeled, with meridians and places in the right positions.
- **Explanation:** The letter explains 15° per hour, the need for a clock that keeps home time at sea, and Harrison's achievement, in clear sentences.

Answer key

1. £20,000 for finding longitude at sea within half a degree (£15,000 for two-thirds of a degree, £10,000 for one degree). It had to be proved on a voyage from Great Britain to the West Indies.
2. Latitude can be read from the height of the North Star or the noon sun. Longitude has no natural starting line; to find it you must know the time at home and the time at the ship at the same moment, and no clock in 1714 could keep good time on a rolling ship.
3. 30 nautical miles, about 35 miles (56 km). Half a degree is 2 minutes of time ($1^\circ = 4$ minutes).
4. A carpenter from Lincolnshire (born 1693 in Yorkshire) who taught himself clockmaking and built the sea clocks H1 to H4. Problems: the rolling of the ship, and heat and cold (also oil and damp). He used balances instead of a pendulum, linked so the ship's motion could not throw them off; he used brass and steel together (later a bimetallic strip) to cancel the effects of heat and cold; he used oily lignum vitae and rollers to avoid sticky oil.
5. 4 seconds of time = 1 minute of arc, so 5 seconds is about $1\frac{1}{4}$ minutes of longitude, roughly $1\frac{1}{4}$ nautical miles. Yes; the limit was half a degree, 30 minutes of longitude.
6. Greenwich time is later, so the ship is west. $4 \text{ hours} \times 15^\circ = 60^\circ$ west.
7. Greenwich time is earlier, so the ship is east. $12:00 - 8:40 = 3 \text{ hours } 20 \text{ minutes}$. $3 \times 15^\circ = 45^\circ$, $20 \div 4 = 5^\circ$, total 50° east.
8. $120 - 90 = 30^\circ$, which is 2 hours. Reno is west, so it is earlier: 10:00 a.m.
9. K1 was Larcum Kendall's copy of Harrison's H4 (finished 1769). Captain Cook carried it on the Resolution on his second voyage, 1772–1775. It kept a steady rate through heat and cold for three years, proving that a copy of H4 could find longitude anywhere.
10. Greenwich is later, so west. $2 \text{ hours} \times 15^\circ = 30^\circ$; $24 \div 4 = 6^\circ$; 36° west. The island is South Georgia.

MAPPING THE WORLD

Explorers could not sail by courage alone. They needed maps, and in this unit you will meet the men who drew the world as it was slowly found. First comes Claudius Ptolemy of Alexandria, who about AD 150 wrote the whole known world as a list of places with latitude and longitude, a book that guided sea captains 1,300 years later, mistakes and all. Then you will travel to the little mountain town of Saint-Dié, where in 1507 Martin Waldseemüller and Matthias Ringmann printed the map that first used the name **America**. Its only surviving copy is now in the Library of Congress.

Next you will meet Gerard Mercator, whose 1569 map let sailors steer a straight compass course, and you will learn why it makes Greenland look as big as Africa when Africa is really about 14 times bigger. Finally you will peel an orange, cover a ball with paper gores and see with your own hands why **every flat map must stretch something**. You will learn to ask of every map: what was it made to do, and what does it give up?

Mapmaking is a work of truth-telling. A good map is built from real measurements, checked against new discoveries and honest about its own limits. Christians have good reason to love that work, because the world we map was made by a God of order who “hath determined the times before appointed, and the bounds of their habitation” (Acts 17:26).

BEFORE YOU BEGIN

- Can read latitude and longitude in whole degrees and knows a degree of latitude is about 69 miles (Unit 2)
- Knows the compass points and can measure an angle with a protractor
- Can multiply and divide whole numbers and simple decimals
- Knows the voyages of Dias (1488) and da Gama (1498) from Unit 1

MASTERY CHECKLIST

- I can tell how Ptolemy listed the world by latitude and longitude, and name two of his mistakes.
- I can tell who named America, why, and where the 1507 map is kept today.
- I can explain how Mercator’s map makes a compass course a straight line and why it makes Greenland look huge.
- I can show with an orange peel or paper gores why no flat map is true in every way.
- I can choose the right map for a job: Mercator, equal-area, compromise or globe.
- I can compare the true areas of lands such as Greenland and Africa using numbers.

OPTIONAL BOOKS AND RESOURCES

- **The Waldseemüller map at the Library of Congress**
(<https://www.loc.gov/item/2003626426/>): Free. A high-resolution scan of the 1507 map

that lets you zoom in on the word America, the portraits of Ptolemy and Vespucci, and the wind heads (Lesson 4.2).

- **The True Size Of...** (<https://www.thetruesize.com/>): Free website. Drag Greenland, Alaska or any country over Africa or the equator on a Mercator map and watch it shrink to its true size (Lessons 4.3 and 4.4). A parent should sit alongside, as with any website.

4.1 PTOLEMY'S GEOGRAPHY ★

OBJECTIVES

- Tell how Claudius Ptolemy of Alexandria wrote down the world as a list of places with latitude and longitude around AD 150.
- Use latitude and longitude in whole degrees to plot places and to find north-south distances (about 69 miles to a degree).
- Explain two big mistakes in Ptolemy's map and how they shaped the voyages of Columbus and the Portuguese.

Warm-up. Hide a coin somewhere on a tabletop. Without pointing or using words like “near the cup,” tell a partner exactly where it is using only two numbers: how many hand-widths from the left edge and how many from the bottom edge. Can they find it? Now swap. You have just done what Ptolemy did for 8,000 places on earth.

Video. Coming soon. Ptolemy's Geography and his world map, the 1482 Ulm edition, and how Columbus used it: search Library of Congress, Smithsonian, The History Guy, Memoria Press; Homeschool Pop (Alternate); Royal Museums Greenwich (candidate, needs vetting).

KEY TERMS

geography

The study of the earth and where things are on it. Ptolemy's book *Geography* was a guide to drawing the whole known world.

coordinates

A pair of numbers that tells exactly where a place is, such as its latitude and longitude.

latitude

How far north or south of the equator a place is, measured in degrees from 0° at the equator to 90° at a pole.

longitude

How far east or west a place is from a chosen starting line, measured in degrees.

prime meridian

The starting line for longitude, numbered 0°. Ptolemy put his at the Fortunate Isles (the Canary Islands); today it runs through Greenwich, England.

CORE IDEAS

The story. About AD 150, in the great harbor city of Alexandria, Egypt, a Greek-speaking scholar named Claudius Ptolemy set out to do something no one had done well before: write down the whole known world so that anyone could draw it. Alexandria was then part of the Roman Empire, and ships and caravans brought travelers' reports from Spain to India.

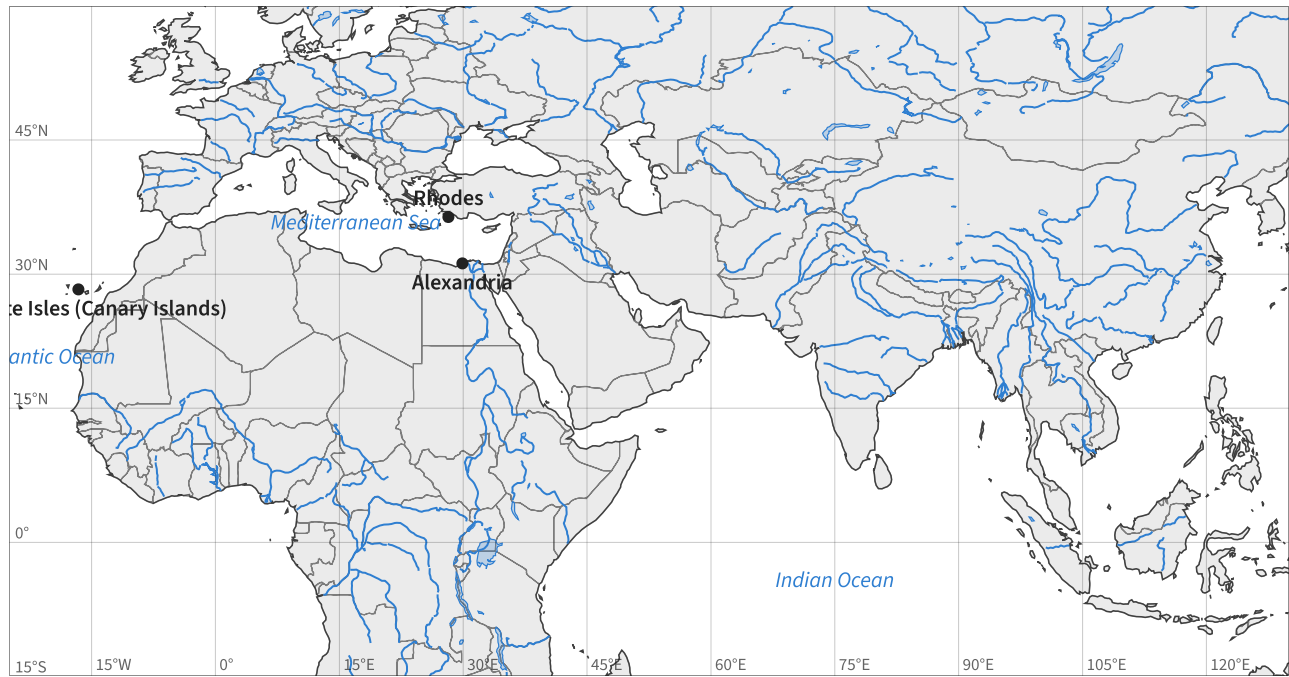
Ptolemy gathered them all into a book called the *Geography*. The surprising thing is that the heart of the book is not a picture. It is a long list of about 8,000 places, each with two numbers beside it.

How it worked. Ptolemy divided the circle of the earth into 360 **degrees**, as Greek astronomers had done before him. For **latitude** he counted degrees north or south from the equator. For **longitude** he needed a starting line, so he chose the farthest land to the west that he knew, the Fortunate Isles, which we call the Canary Islands. That was his **prime meridian**. Every city, river mouth and cape got a latitude and a longitude east of that line. He listed Alexandria at 31 degrees north and about 60½ degrees east. With his list and his instructions for drawing a round earth on a flat sheet, a mapmaker could draw the world again even if every old drawing were lost.

The big idea. Ptolemy's method was brilliant, but some of his numbers were wrong. Latitudes could be measured from the height of the sun or the stars, so many were close. Longitude was much harder, and Ptolemy had to guess it from how many days travelers said a trip took. Their guesses ran long, so he stretched Europe and Asia far too wide: his known world covered 180 degrees, half the globe, when the real span from the Canaries to China is about 140. He also used a figure for the size of the earth that was too small, smaller than the one Eratosthenes had found nearly 400 years earlier. And he drew an unknown land joining southern Africa to Asia, which turned the Indian Ocean into a closed lake.

How the book traveled. For about a thousand years western Europe forgot the *Geography*, but Greek scholars in Constantinople copied it and Arab geographers studied it. Around 1406 it was translated into Latin in Florence, and from 1477 it was printed with maps. Suddenly every serious sea captain and prince could own Ptolemy's world. Columbus read writers who used a small earth and a stretched Asia, and he added up the numbers to make the ocean west of Spain look narrow enough to cross. Meanwhile the Portuguese proved Ptolemy wrong in the other direction: when Bartolomeu Dias rounded the Cape of Good Hope in 1488, the Indian Ocean turned out to be open sea.

On the map. Look at any globe today and you will see Ptolemy's idea: a net of latitude and longitude lines that gives every place on earth its own address. Explorers spent the next 300 years fixing his numbers, with the quadrant for latitude and, at last, Harrison's clock for longitude. But they kept his method. A good map is not only a picture; it is a list of true measurements, and it can be checked and corrected. That is a lesson for all of us: test what you are told, and when you find a better measurement, change the map.



Ptolemy's known world. He started counting longitude at the Fortunate Isles (Canary Islands) and gave Alexandria and Rhodes their latitudes from careful measurements.

PICTURE STUDY



World map from Ptolemy's Geography (Ulm edition), Johannes Schnitzer of Armsheim (woodcut), after Claudius Ptolemy; printed by Lienhart Holle, 1482 · Hand-colored woodcut · Printed in Ulm, Germany; copies are kept in several great libraries

No map drawn by Ptolemy himself has survived. What survived was his list of places and his instructions. About 1,300 years later, mapmakers in Europe used them to draw the world again. This map comes from an edition printed in Ulm, Germany, in 1482, one of the first

printed north of the Alps. A woodcarver cut the map into a block of wood so that it could be printed again and again, and then the copies were colored by hand.

Ten years after this map was printed, Columbus sailed west. So this is very close to the picture of the world that the first great explorers carried in their heads.

Look closely

- Find the faces around the edge. They are the winds, blowing from every direction.
- Find the Indian Ocean. What closes it in at the bottom? Is that really there?
- Look at the lines of longitude. How do they change as they go north toward the top?
- Look for the Americas. Why are they missing?

Talk about it

1. Which parts of this map look almost right to you, and which look wrong?
2. Why would a sailor in 1482 trust this map, even with its mistakes?
3. If you could send Ptolemy one correction, what would it be?

PROJECT: PTOLEMY'S TABLE: DRAW A MAP FROM NUMBERS

Ptolemy did not hand down a picture. He handed down a table of numbers. You will draw the Mediterranean world from a table, just as mapmakers in Florence and Ulm did, and then see what one wrong number does to a map.

You will need

- Graph paper (1/4-inch squares) and a pencil
- Ruler and colored pencils
- The coordinate table in the steps below

Steps

1. Near the bottom of your page, draw a line and mark it 30°N. Count up 2 squares for every degree and mark 35°N, 40°N and 45°N. These are your latitude lines.
2. Along the bottom, mark longitude from 10°W at the left to 40°E at the right, 1 square for every 2 degrees. Mark 0° clearly: that is today's prime meridian at Greenwich.
3. Plot these places with a dot and a label: Gibraltar 36°N 5°W; Marseille 43°N 5°E; Rome 42°N 12°E; Carthage (near Tunis) 37°N 10°E; Athens 38°N 24°E; Constantinople (Istanbul) 41°N 29°E; Rhodes 36°N 28°E; Alexandria 31°N 30°E; Jerusalem 32°N 35°E; Antioch 36°N 36°E.
4. Using an atlas as a guide, sketch the coast of the Mediterranean Sea so that it passes near your port cities. Color the sea blue.
5. Now play the copyist. Have a parent secretly change one number in the table (for example, Rome at 42°N 22°E). Plot the wrong Rome in red. How far off is it?
6. Write a sentence: Why did mapmakers who copied Ptolemy's table by hand need to be very careful?

Tips

- Latitude first, then longitude, just as Ptolemy listed them.
- Remember that west longitudes go to the left of 0° and east longitudes go to the right.

Check your work

- I can plot a place from its latitude and longitude.
- My ten places are in the right order from west to east.
- I can explain why one copying mistake could move a city across the sea.

MAP NOTEBOOK

1. Draw the world as Ptolemy saw it in a simple sketch: Europe, Africa, Asia and a closed Indian Ocean. Label the Fortunate Isles as his 0° line.
2. Make a two-column chart titled “Ptolemy Got It Right / Ptolemy Got It Wrong” with at least two items in each column.
3. Write your own home’s latitude and longitude in whole degrees (ask a parent to help you look it up) and draw a small grid showing where it falls.

From history. The Latin translation of the *Geography* was finished in Florence in the early 1400s by a scholar named Jacopo Angeli, and printed editions with maps followed in Bologna in 1477 and Ulm in 1482. Printing changed everything: a hand-copied atlas took months to make, but a printer could make hundreds of identical copies. Within a few years, map makers began adding “new maps” at the back of Ptolemy’s book to show coasts that the Portuguese and Spanish sailors had found, so the old book and the new discoveries traveled together.

WORKED EXAMPLES

Example 1. Ptolemy measured Alexandria at about 31°N . The island of Rhodes, nearly due north across the sea, is at about 36°N . About how far apart are they from north to south? (One degree of latitude is about 69 miles.)

(Use the map or drawing “Rhodes lies about 5 degrees of latitude north of Alexandria.” shown earlier in this lesson.)

1. Both places are north of the equator, so subtract: $36^\circ - 31^\circ = 5^\circ$.
2. Each degree of latitude is about 69 miles: $5 \times 69 = 345$ miles.
3. In kilometers: $5 \times 111 = 555$ km.

Answer: About 345 miles (about 555 km) from north to south.

Example 2. Ptolemy's known world stretched 180° east from the Fortunate Isles to the far side of Asia. In truth, the Canary Islands are at about 16°W and the coast of China near Shanghai is at about 122°E . How wide is the real span? And how many degrees of open globe did Ptolemy leave between the far side of Asia and the Canaries, going west?

1. One place is west of Greenwich and one is east, so add: $16^\circ + 122^\circ = 138^\circ$. The real span is about 138° .
2. A full circle is 360° . On Ptolemy's map, the rest of the globe is $360^\circ - 180^\circ = 180^\circ$.
3. On the real earth, the rest is $360^\circ - 138^\circ = 222^\circ$, and two whole continents, North and South America, sit in it.

Answer: The real span is about 138° , not 180° . Ptolemy left 180° of globe going west from the Canaries to Asia; the real gap is about 222° , so the westward ocean looked much narrower on his map than it is.

PRACTICE

1. **EASY** In what city did Ptolemy live and work, and about when did he write his *Geography*?
2. **EASY** What two numbers did Ptolemy give for each of his 8,000 places?
3. **EASY** Where did Ptolemy put his prime meridian (0° of longitude), and why there?
4. **MEDIUM** Athens is at about 38°N and Alexandria at about 31°N . How many degrees apart are they from north to south, and about how many miles?
5. **MEDIUM** Look at the map of Ptolemy's known world. Which is farther north, Rhodes or Alexandria? Which is farther west, the Canary Islands or Alexandria?
(Use the map or drawing "Use the grid lines to compare the places." shown earlier in this lesson.)
6. **MEDIUM** Ptolemy listed Alexandria at about $60\frac{1}{2}^\circ$ east of the Fortunate Isles. Measured from the westernmost Canary Island, the true figure is about 48° . By how many degrees did Ptolemy stretch the distance?
7. **HARD** Ptolemy drew the Indian Ocean as a closed sea with land along its southern side. Which Portuguese voyages proved him wrong, and when?
8. **CHALLENGE** In two or three sentences, explain how a too-small earth and a too-wide Asia made a voyage west from Spain look easier than it really was.

COMMON MISTAKES

- Thinking Ptolemy drew one famous map. He wrote a list of coordinates and instructions; the maps we see were drawn from them more than a thousand years later.
- Mixing up latitude and longitude. Latitude is north or south of the equator; longitude is east or west of the prime meridian.
- Thinking an old map is worthless because it has mistakes. Ptolemy's method was right, and later explorers corrected his numbers instead of throwing it away.

Make it a game • Ptolemy Says. Draw a 10-by-10 grid on paper and number the lines like latitude and longitude. One player secretly places five “cities” on crossing points. The other calls out coordinates, latitude first, such as “4 north, 7 east.” A hit earns a point; a miss gets a clue: “go north” or “go west.” The caller must always say latitude first or lose the turn. Switch after five hits.

Scripture. “It is he that sitteth upon the circle of the earth, and the inhabitants thereof are as grasshoppers; that stretcheth out the heavens as a curtain, and spreadeth them out as a tent to dwell in:” (Isaiah 40:22, KJV)

Ptolemy measured the earth by the steady movements of the sun and stars. The order of the heavens is not an accident; the God who stretched them out made a world that can be measured and mapped.

Practice answers

1. In Alexandria, Egypt, about AD 150.
2. Its latitude and its longitude, in degrees.
3. At the Fortunate Isles (the Canary Islands), because they were the farthest west land he knew, so every other place could be counted east of them.
4. $38 - 31 = 7^\circ$. $7 \times 69 = 483$ miles (about 777 km).
5. Rhodes is farther north. The Canary Islands are farther west.
6. $60\frac{1}{2} - 48 = 12\frac{1}{2}$ degrees too far east.
7. Bartolomeu Dias rounded the Cape of Good Hope in 1488, showing the ocean was open, and Vasco da Gama sailed on around Africa to India in 1498.
8. If the whole earth is small and Asia stretches very far east, then the stretch of ocean left between Spain and Asia, going west, looks short. Columbus added up such numbers and thought Asia was only a few thousand miles away. In truth the ocean was much wider, and the Americas lay in between.

4.2 WALDSEEMÜLLER NAMES AMERICA

OBJECTIVES

- Tell how Martin Waldseemüller and Matthias Ringmann of Saint-Dié printed the 1507 world map that first used the name “America.”
- Describe what the map got right and wrong, and why its one surviving copy is kept at the Library of Congress.
- Use latitude to find north-south distances and use a grid to enlarge a map by sheets.

Warm-up. Take a sheet of paper and write the name of a brand-new island you have “discovered.” Now ask: who should it be named after? The first person to see it, the person who proved it was new, the person who paid for the trip, or the people already living there? Talk it over for five minutes. Mapmakers in 1507 had to answer the same question.

Watch. *Amerigo Vespucci* (Drive Thru History with Dave Stotts, 1:54).

<https://www.youtube.com/watch?v=8zf21pvNhMQ>

After the story: watch to learn who Amerigo Vespucci was and how Waldseemüller turned his name into “America” on the 1507 map.

Note: Captions were not available to check; preview it first. It comes from a trusted Christian history channel and is short (under 2 minutes).

KEY TERMS

cosmography

An old word for the description of the whole world and the heavens. Waldseemüller’s map was called a *Universalis Cosmographia*, a description of the whole world.

woodcut

A picture carved into a block of wood, inked and pressed onto paper so that many copies can be printed.

New World

The name Europeans gave to the Americas after 1500, because these lands were new to them. Millions of people already lived there.

inset

A small extra map placed inside the border of a larger map.

continent

One of the great land masses of the earth, such as Africa, Asia or South America.

CORE IDEAS

The story. In April 1507, in the small town of Saint-Dié in the Vosges Mountains of what is now eastern France, a few scholars finished a great printing job. Martin Waldseemüller, a

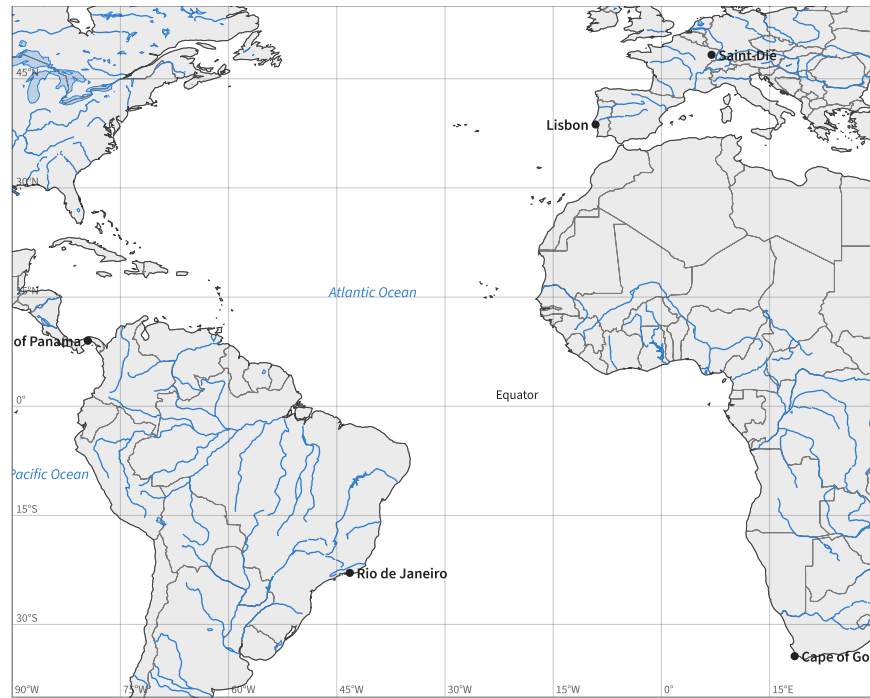
mapmaker, and his friend Matthias Ringmann, a poet and teacher, had made a world map on twelve woodcut sheets that fit together into a wall map about 4½ feet tall and 8 feet wide. They printed about 1,000 copies, with a little book to go with it. Fifteen years after Columbus first crossed the Atlantic, their map did something no map had done before. Across a long, thin land in the western ocean, it printed one new word: **America**.

How they figured it out. Columbus had died in 1506 still believing he had reached the edge of Asia. But an Italian sailor and merchant from Florence named Amerigo Vespucci, who sailed for Spain and then Portugal, wrote letters that were printed all over Europe. He described a long coast running far south, below the equator, and said these lands were a new world, not part of Asia. Waldseemüller and Ringmann believed him. In their little book they explained their choice: since Europe and Asia had been named after women in old stories, they saw no reason why this new part of the world should not be called America, after Amerigo, who had found it out. They wrote the name in Latin form, as scholars did. Historians still argue about whether all of Vespucci's voyages happened as he told them, but the name stuck.

The big idea. The map is a picture of the moment when the old world picture broke open. Most of it still follows Ptolemy, whose portrait sits at the top left beside a small inset map of the old world. At the top right sits Vespucci with an inset of the new lands. Africa now has a true southern tip, thanks to Dias. And most amazing of all, the map shows a separate continent with a wide ocean beyond it, six years before Vasco Núñez de Balboa became the first European to see the Pacific from Panama in 1513. No one knows exactly how Waldseemüller guessed it.

Telling it honestly. The Americas were new to Europeans, not to the people who lived there. Millions of people, from the Taíno of the Caribbean islands to the great cities of Mexico and the Andes, had their own names for their lands. Europeans who came after 1507 brought good things, such as the Christian gospel, and terrible things, such as conquest and slavery, which we will look at plainly in Unit 8. Waldseemüller himself seems to have had second thoughts about the name: in later maps he left it off. But in 1538 Gerard Mercator, whom you will meet next week, printed "America" on both the northern and southern continents, and after that it was settled.

On the map. Of the 1,000 copies, only one survived. Bound into a book in a German castle, it was forgotten until 1901, when a Jesuit priest and teacher named Joseph Fischer found it at Wolfegg Castle in southern Germany. In 2003 the Library of Congress in Washington, D.C., bought it for 10 million dollars, and it is now on display there. People call it "America's birth certificate." Every time you write the name of your country or your continent, you are using a word first printed by two scholars in a small mountain town.



The places of this story. Waldseemüller printed his map in Saint-Dié in 1507; Balboa did not see the Pacific from Panama until 1513.

PICTURE STUDY



Universalis Cosmographia (the Waldseemüller map), Martin Waldseemüller, with Matthias Ringmann, 1507 · Woodcut printed on twelve sheets · Library of Congress, Washington, D.C.

Martin Waldseemüller was a German mapmaker who worked with a small group of scholars in Saint-Dié. The full Latin title of his map means “A drawing of the whole world, following the tradition of Ptolemy and the voyages of Amerigo Vespucci and others.” That title tells you the story: an old map and new discoveries side by side.

The map is drawn on a curved, heart-like shape so that it can show the whole round world on a flat wall. It is the oldest surviving map to use the name America, and it is the only copy of its printing known to exist.

Look closely

- Find the two men at the top. Which one is Ptolemy (the old world) and which is Vespucci (the new)?
- Find the word America. Is it on North America or South America?
- Look at the far left. What is drawn west of the new lands?
- Look at the edges of the map. How does the mapmaker show that the world is round?

Talk about it

1. Why do you think the mapmakers put both Ptolemy and Vespucci at the top?
2. What did this map show that no European had yet seen with his own eyes?
3. Why is it fitting that the one surviving copy is kept in the United States?

PROJECT: A TWELVE-SHEET WORLD MAP

Waldseemüller's map was too big to print in one piece, so he printed it in twelve sheets, three rows of four, and fitted them together. You will make your own twelve-sheet wall map by the grid method that mapmakers have used for centuries.

You will need

- A printed outline map of the world, about 8½ by 11 inches
- Ruler and pencil
- 12 sheets of plain paper
- Tape, markers or colored pencils

Steps

1. Lay the printed world map sideways (11 inches wide). Draw a grid on it of 4 columns and 3 rows. Number the boxes 1 to 12, left to right, top row first.
2. Number your 12 blank sheets 1 to 12 in the corner.
3. Look at box 1 on the small map. Copy what is in that box onto sheet 1, making it fill the whole sheet. Watch where each coast enters and leaves the edges of the box.
4. Do the same for all 12 sheets. Check that the coasts line up where two sheets touch.
5. Tape the sheets together in 3 rows of 4. Measure your finished map and write its height and width on the back.
6. Label the continents and oceans. Write "America" in the place Waldseemüller put it, and add a small note telling why he chose that name.

Tips

- Divide each box into four smaller boxes with light pencil lines on both maps. It makes copying the coast much easier.
- Work around the map from one sheet to its neighbor so that the edges match.

Check your work

- My twelve sheets fit together without gaps.
- Coastlines line up from sheet to sheet.
- I can tell how many times bigger my map is than the original printout.

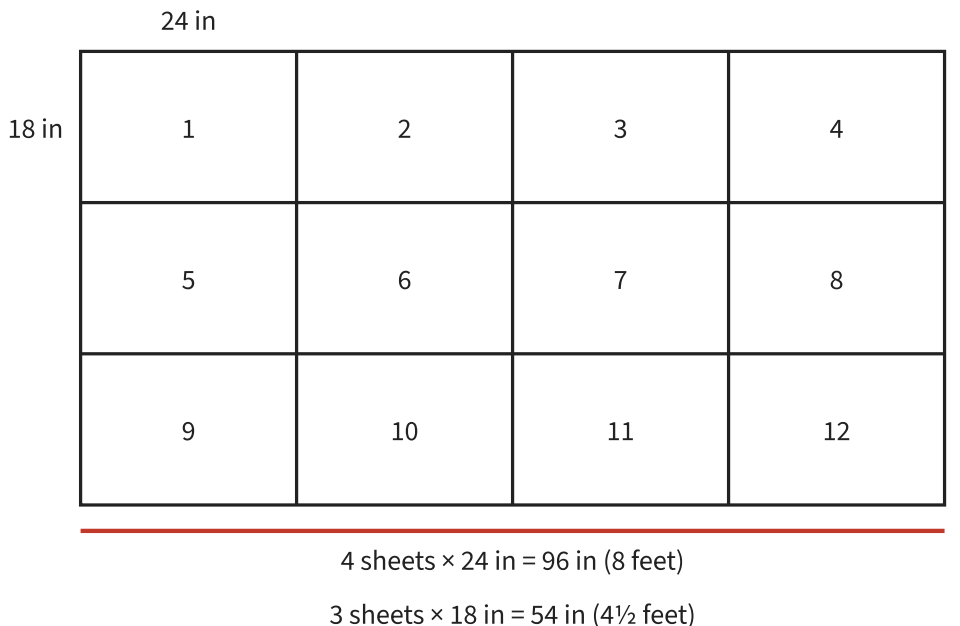
MAP NOTEBOOK

1. Sketch the outline of the Waldseemüller map and mark where Ptolemy, Vespucci and the word America appear.
2. Draw a timeline from 1488 to 1538 with these events: Dias rounds the Cape (1488), Columbus's first voyage (1492), da Gama reaches India (1498), the Waldseemüller map (1507), Balboa sees the Pacific (1513), Mercator puts America on both continents (1538).
3. Write a short paragraph: Should America have been named after Vespucci, Columbus or someone else? Give one reason.

From history. Waldseemüller and Ringmann did not only make a wall map in 1507. They also printed a set of globe gores, twelve pointed strips that could be cut out and glued onto a ball to make a small globe, also bearing the name America. A few copies of these gores survive. You will make gores of your own in Lesson 4.4.

WORKED EXAMPLES

Example 1. The Waldseemüller map was printed on 12 sheets in 3 rows of 4. Each sheet is about 18 inches tall and 24 inches wide. How tall and how wide is the whole map, in inches and in feet?



How the twelve sheets fit together.

1. Height: 3 rows $\times$ 18 inches = 54 inches. $54 \div 12 = 4\frac{1}{2}$ feet.
2. Width: 4 columns $\times$ 24 inches = 96 inches. $96 \div 12 = 8$ feet.
3. In metric, that is about 1.4 m by 2.4 m.

Answer: About 54 inches by 96 inches, or 4½ feet tall and 8 feet wide.

Example 2. Waldseemüller's map showed Africa's true southern tip, which Dias had rounded in 1488. Lisbon is at about 39°N and the Cape of Good Hope at about 34°S. About how far apart are they from north to south? (1° of latitude $\approx$ 69 miles.)

(Use the map or drawing "From Lisbon to the Cape of Good Hope crosses the equator." shown earlier in this lesson.)

1. One place is north of the equator and one is south, so add: $39^\circ + 34^\circ = 73^\circ$.
2. Multiply by 69 miles: $73 \times 69 = 5,037$ miles.
3. In kilometers: $73 \times 1.11 = 8,103$ km.

Answer: About 5,040 miles (about 8,100 km) from north to south, and the real sailing route was much longer because ships swung far out into the Atlantic.

PRACTICE

1. **EASY** After whom was America named, and what was his home city?
2. **EASY** Where is the only surviving copy of the 1507 Waldseemüller map kept today?
3. **EASY** On which continent did Waldseemüller print the word America: North America or South America?
4. **MEDIUM** The map was found in 1901 and bought by the Library of Congress in 2003. How many years passed between the two? How many years passed from the printing in 1507 to the purchase?
5. **MEDIUM** Balboa first saw the Pacific Ocean in 1513. How many years after the Waldseemüller map was that? Why does this make the map surprising?
6. **MEDIUM** Use the map of this story. Saint-Dié is at about 48°N and Rio de Janeiro at about 23°S. About how many degrees and how many miles apart are they from north to south?
(Use the map or drawing “One place is north of the equator and one is south.” shown earlier in this lesson.)
7. **HARD** A museum makes a copy of the map at half size. Each sheet was 18 by 24 inches. How big is each sheet of the copy, and how big is the whole copy in feet?
8. **CHALLENGE** Europeans called the Americas the “New World.” In two or three sentences, explain in what way the name is true and in what way it is not.

COMMON MISTAKES

- Thinking Columbus named America or knew he had found a new continent. He died believing he had reached Asia.
- Thinking Waldseemüller put “America” on North America. He wrote it on South America; Mercator later used it for both.
- Calling the Americas empty. Millions of people lived there long before any European ship arrived.

Make it a game • Name That Place. Take turns reading out a place name, and the other players guess whom or what it is named after: America (Amerigo Vespucci), the Strait of Magellan (Ferdinand Magellan), Hudson Bay (Henry Hudson), Virginia (Queen Elizabeth I, the “Virgin Queen”), the Cape of Good Hope (named for the hope of reaching India). Score a point for each right answer and a bonus point if you can find the place on a globe within ten seconds.

Scripture. “And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;” (Acts 17:26, KJV)

The peoples of the Americas and the peoples of Europe were all of one blood, made by one God, though they had never met. Maps changed in 1507, but God had known every nation and every land from the beginning.

Practice answers

1. Amerigo Vespucci, of Florence, Italy.
2. At the Library of Congress in Washington, D.C.
3. South America.
4. $2003 - 1901 = 102$ years. $2003 - 1507 = 496$ years.
5. $1513 - 1507 = 6$ years. The map already showed a wide ocean west of America before any European had seen it.
6. $48 + 23 = 71^\circ$. $71 \times 69 = 4,899$, about 4,900 miles (about 7,900 km).
7. Each sheet is 9 by 12 inches. The whole copy is $3 \times 9 = 27$ inches ($2\frac{1}{4}$ feet) tall and $4 \times 12 = 48$ inches (4 feet) wide.
8. It is true that these lands were new to Europeans and were not on Ptolemy's map, so the world was bigger than they had thought. But the lands were not new to the millions of people already living there, who had their own names, towns and nations.

4.3 MERCATOR'S PROJECTION

OBJECTIVES

- Tell the story of Gerard Mercator and his 1569 world map made “for the use of sailors.”
- Explain how Mercator’s map turns a steady compass course (a rhumb line) into a straight line, and why that makes lands far from the equator look too big.
- Compare real areas, such as Greenland and Africa or Alaska and Mexico, and find how much Mercator’s map stretches lands at 60°N.

Warm-up. Take a clean orange or a ball and draw a short “ship’s course” on it with a marker, heading northeast. Now try to keep heading exactly northeast all the way up toward the top. What shape does your path make? Could you draw that path with a ruler on a flat sheet of paper?

Video. Coming soon. Gerard Mercator, the 1569 world map and why Greenland looks so big on a Mercator map: search Smithsonian, Library of Congress, The History Guy, Memoria Press; Homeschool Pop (Alternate); Royal Museums Greenwich and Jay Foreman Map Men (candidates, need vetting).

KEY TERMS

map projection

A way of drawing the round earth on a flat sheet. Every projection changes something: sizes, shapes, distances or directions.

Mercator projection

Mercator’s 1569 way of drawing the world, with straight, parallel lines of longitude and latitude lines spread farther apart toward the poles.

rhumb line

A course that keeps the same compass direction the whole way. On a Mercator map it is a straight line.

bearing

A compass direction measured in degrees clockwise from north. East is 90°, south is 180°.

distortion

The way a flat map changes the true sizes, shapes or distances of the round earth.

atlas

A book of maps. Mercator was the first to use the word for a collection of maps.

CORE IDEAS

The story. In 1569, in the German river town of Duisburg, a mapmaker named Gerard Mercator printed a world map on eighteen sheets, about 4 feet tall and 6½ feet wide. Its Latin title said it was made “for the use of sailors.” Mercator had been born in 1512 in

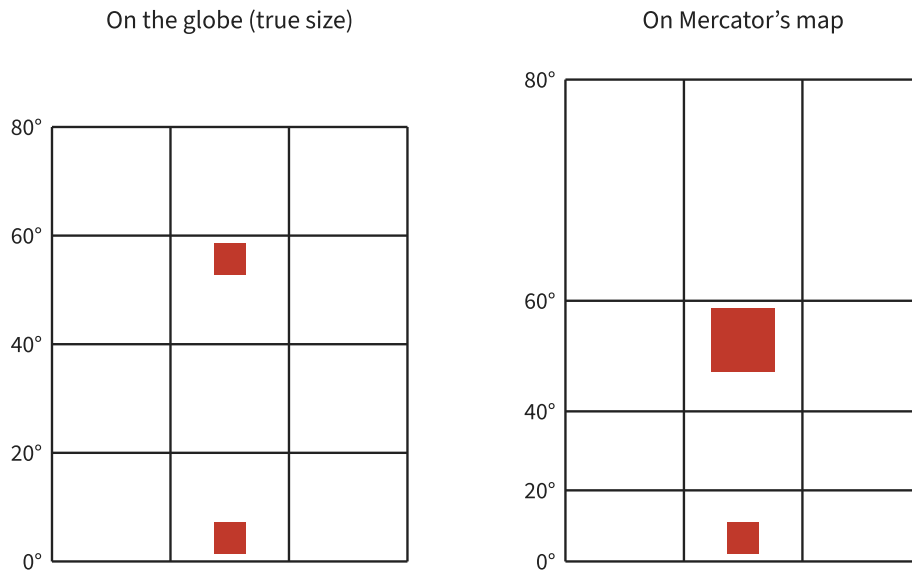
Rupelmonde, in Flanders, to a poor family. He studied at the university in Leuven, learned to make globes and instruments, and became the finest mapmaker in Europe. His life was not easy: in 1544 he was arrested on suspicion of heresy, because of his Protestant leanings, and held in prison for about seven months before he was set free. A few years later he moved his family to Duisburg, where he worked for the rest of his life.

How it worked. A sailor with a compass steers a **bearing**: northeast, say, or 45° . A course that keeps the same bearing is called a **rhumb line**. On a globe, the lines of longitude crowd together toward the poles, so a rhumb line bends into a long curve that spirals toward the pole. On the flat maps of 1569, a straight line between two ports was not a steady compass course, and sailors went wrong. Mercator's answer was bold. He drew every line of longitude straight up and down and parallel, which stretches the far north and far south sideways. Then, at each latitude, he stretched the map north and south by exactly the same amount. Because each little piece is stretched equally both ways, every angle comes out right. Now a navigator could lay a ruler from port to port, measure the angle from north, and steer that bearing.

The big idea. There was a price to pay, and you can see it on every Mercator map. The farther a land is from the equator, the bigger it is drawn. At 30° north, lands are drawn about 1.15 times too wide and too tall. At 60° north they are drawn twice as wide and twice as tall, so they look four times their true area. Near the poles the stretching grows without end, which is why a Mercator map can never show the North Pole or the South Pole. Greenland, far in the north, covers about 836,000 square miles (2.2 million km^2). Africa, across the equator, covers about 11.7 million square miles (30 million km^2), about 14 times as much. Yet on a Mercator map Greenland looks nearly as big as Africa.

Technology overcoming geography. Mercator did not explain the arithmetic behind his spacing. Thirty years later, in 1599, the English mathematician Edward Wright published tables that let any chartmaker draw the grid exactly. Over the next hundred years, Mercator charts became the sailor's standard tool, alongside the quadrant for latitude and, later, Harrison's chronometer for longitude. Nautical charts are still drawn on Mercator's projection today, and many map apps on phones use a version of it, because streets and corners keep their right shapes when you zoom in.

On the map. Mercator was a man of faith as well as skill. Near the end of his life he planned a great book of maps, together with a description of the creation of the world, and named it after Atlas, a wise king of old stories who was said to study the heavens. His son published it in 1595, the year after Mercator died, and ever since a book of maps has been called an **atlas**. When you see Greenland swell on a classroom map, remember that the map is not lying to you. It was built to keep directions true for sailors, and it pays for that with size. A wise map reader always asks: what was this map made to do?

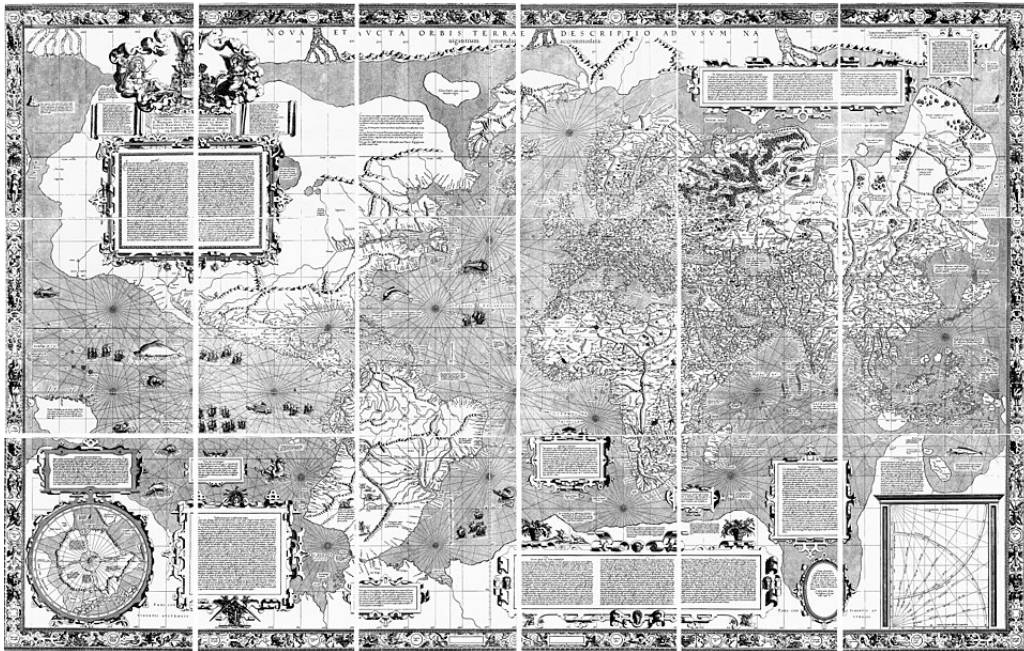


The red squares are all the same real size.

At 60°N, Mercator draws a square 2 times wider and 2 times taller.

On the globe, each 20 degrees of latitude is the same distance. Mercator spreads the lines farther apart toward the pole, so a square of land at 60°N is drawn 2 times wider and 2 times taller.

PICTURE STUDY



Nova et Aucta Orbis Terrae Descriptio ad Usum Navigantium (New and Improved Description of the World, for the Use of Sailors), Gerard Mercator, 1569 · Engraving printed on eighteen sheets · Surviving copies are kept in Paris (Bibliothèque nationale de France), Basel (University Library) and Rotterdam (Maritime Museum)

Gerard Mercator engraved this map on copper plates, so that its lines are fine and sharp. It is covered with Latin notes about the lands and seas, and with long straight lines that radiate

from compass roses across the oceans. Those are rhumb lines, the steady compass courses that a sailor could follow.

Mercator had to guess at much of the world. Look at the huge southern land across the bottom: no one had yet seen Antarctica, but many scholars believed a great southern continent must balance the lands of the north.

Look closely

- Find the straight lines that cross the oceans from compass roses. What were they for?
- Compare the size of Greenland and the far north with Africa. What do you notice?
- Find the small round map in a lower corner. It shows the North Pole, which the big map cannot show. What does Mercator draw there?
- Look at the grid. Are the lines of latitude evenly spaced from bottom to top?

Talk about it

1. Why would a sailor love this map even though it makes some lands too big?
2. Which parts of the world did Mercator know well in 1569, and which did he have to guess?
3. Why do you think he put a separate little map of the North Pole in the corner?

PROJECT: DRAW A MERCATOR GRID AND SAIL A RHUMB LINE

You will draw two grids side by side, an ordinary grid with even spacing and a Mercator grid using real spacing from Edward Wright's method. Then you will draw same-sized "countries" on both and plot a ship's course with a ruler and protractor.

You will need

- Two sheets of plain paper (8½ by 11 inches)
- Ruler marked in tenths of an inch, or a centimeter ruler (see tips)
- Protractor, pencil and two colored pencils

Steps

1. Plain grid: on the first sheet, draw a line near the bottom for the equator (0°). Draw latitude lines every 1 inch above it for 10°, 20° and up to 70°. Draw longitude lines every 1 inch across the page.
2. Mercator grid: on the second sheet, draw the equator near the bottom and longitude lines every 1 inch as before. Draw the latitude lines this far above the equator: 10° at 1.0 in, 20° at 2.0 in, 30° at 3.1 in, 40° at 4.4 in, 50° at 5.8 in, 60° at 7.5 in, 70° at 9.9 in.
3. On both grids, color three "countries" that are each one box: from 0° to 10°, from 30° to 40°, and from 60° to 70°. Measure each box's height on the Mercator grid and write it inside.
4. Remember that on the real earth a 10° box at 60°-70° is only about half as wide as one at the equator. Write how the Mercator grid shows it instead.

5. Rhumb line: on the Mercator grid, mark a home port at 10°N and a far port at 50°N , four columns to the right. Draw a straight line between them with your ruler.
6. Draw a short north arrow straight up from your home port. Use the protractor to measure the angle from the north arrow to your course line. That angle is the bearing a sailor would steer the whole way. (You should get about 40° , a little north of northeast.)

Tips

- If your ruler is in centimeters, use 2 cm for every 10° of longitude and double all the Mercator spacings (10° at 2.0 cm, 20° at 4.0 cm, and so on); the grid will be smaller but the same shape.
- Measure every latitude line from the equator, not from the line below it, so small errors do not add up.

Check your work

- My Mercator latitude lines get farther apart toward the top.
- I can tell how much taller my 60° – 70° box is than my 0° – 10° box.
- I measured a bearing for my rhumb line and can explain why a sailor could follow it with a compass.

MAP NOTEBOOK

1. Sketch Greenland and Africa as they look on a Mercator map, then write their true areas underneath: about 836,000 and 11.7 million square miles.
2. Draw a compass rose with N, NE, E, SE, S, SW, W, NW and write the bearing in degrees beside each (N = 0° , NE = 45° , E = 90° , and so on).
3. Write two sentences: What is Mercator's map good for? What is it not good for?

From history. Mercator's map came long before sailors could find longitude at sea. In 1569 a navigator could fix his latitude with a quadrant but still had to guess how far east or west he had gone. That is why Mercator's straight compass courses were so valuable: if you could not know your exact position, at least you could hold a true course. When Harrison's chronometers arrived two centuries later, the Mercator chart and the marine clock together let captains plot their exact position each day.

WORKED EXAMPLES

Example 1. A square patch of land at 60°N measures 100 miles on each side. Mercator's map draws everything at 60°N twice as wide and twice as tall as it would draw the same land at the equator. How big does the patch look, and how many times its true area is that?

(Use the map or drawing "Twice as wide and twice as tall makes four times the area." shown earlier in this lesson.)

1. Width as drawn: $100 \times 2 = 200$ miles. Height as drawn: $100 \times 2 = 200$ miles.
2. Area it looks like: $200 \times 200 = 40,000$ square miles.
3. True area: $100 \times 100 = 10,000$ square miles.
4. $40,000 \div 10,000 = 4$.

Answer: It looks like a 200-by-200-mile square, 40,000 square miles, which is 4 times its true area.

Example 2. Africa covers about 11,700,000 square miles. Greenland covers about 836,000 square miles. About how many Greenlands would fit inside Africa?

1. Divide the larger area by the smaller: $11,700,000 \div 836,000$.
2. Make it easier by rounding Greenland to 840,000 and dividing both by 1,000:
 $11,700 \div 840 \approx 13.9$.
3. Round to a whole number: about 14.

Answer: About 14 Greenlands would fit inside Africa, even though they look nearly the same size on a Mercator map.

PRACTICE

1. **EASY** In what year did Mercator print his famous world map, and for whom did he say it was made?
2. **EASY** What is a rhumb line, and how does it look on a Mercator map?
3. **EASY** What bearing in degrees is due east? Due south? Southwest?
4. **MEDIUM** Look at the two grids. On which grid are the latitude lines evenly spaced? On Mercator's grid, which band is taller: 0° to 20° or 60° to 80°?
(Use the map or drawing "Compare the spacing of the latitude lines." shown earlier in this lesson.)
5. **MEDIUM** On a Mercator map, Alaska looks much bigger than Mexico. Alaska covers about 665,000 square miles; Mexico covers about 762,000. Which is really bigger, and by about how much? Why does the map fool us?
6. **MEDIUM** At the equator, one degree of longitude is about 69 miles wide. At 60°N it is only about $34\frac{1}{2}$ miles wide on the real earth, but Mercator draws it just as wide as at the equator. How many times is it stretched?

7. **HARD** Why can a Mercator map never show the North Pole?
8. **CHALLENGE** South America covers about 6.9 million square miles and Greenland about 0.84 million. About how many times bigger is South America? Name one kind of map that would show this difference truly.

COMMON MISTAKES

- Thinking Greenland really is as big as Africa or South America. Africa is about 14 times bigger and South America about 8 times bigger.
- Thinking Mercator made a mistake. He stretched the far north on purpose, so that compass courses would be straight lines for sailors.
- Thinking a straight line on a Mercator map is the shortest route. It is the steady-bearing route; the shortest route on the globe usually looks curved on this map.

Make it a game • Bigger or Smaller?. Lay a Mercator world map on the table. A parent names two places, such as Greenland and Australia, Alaska and Mexico, or Scandinavia and India. Each player guesses which is really bigger and how many times. Check the answers on a globe or an equal-area map (or the true areas in an almanac). Score a point for the right one and a bonus point if your “how many times” guess is within 1. Most surprises win the round.

Scripture. “He stretcheth out the north over the empty place, and hangeth the earth upon nothing.” (Job 26:7, KJV)

Mercator stretched the north on paper to help sailors find their way, and he joined his maps to a study of God’s creation. The real north is stretched out by God, and no mapmaker can draw it perfectly on a flat sheet.

Practice answers

1. 1569, for the use of sailors.
2. A course that keeps the same compass bearing the whole way. On a Mercator map it is a straight line.
3. East is 90° , south is 180° , southwest is 225° .
4. The globe grid is evenly spaced. On Mercator’s grid, the band from 60° to 80° is much taller.
5. Mexico is bigger, by about $762,000 - 665,000 = 97,000$ square miles. Alaska lies far north, where Mercator’s map stretches lands, while Mexico lies close to the equator.
6. $69 \div 34\frac{1}{2} = 2$. It is stretched 2 times.
7. On the globe, the lines of longitude all meet at the pole, but Mercator keeps them apart. The closer you get to the pole, the more he must stretch the map, and at the pole itself the stretching would have no end, so the map would be infinitely tall.
8. $6.9 \div 0.84 \approx 8$, so South America is about 8 times bigger. An equal-area map (or a globe) shows the true difference.

4.4 PROJECTIONS COMPARED

OBJECTIVES

- Explain why no flat map can show the round earth truly in every way, using an orange peel and paper gores on a ball.
- Compare a globe, a Mercator map, an equal-area map and a compromise map, and tell what each keeps true and what it gives up.
- Choose the right kind of map for a job and use areas to compare Greenland, Africa and other lands correctly.

Warm-up. Peel a clementine or orange in as few pieces as you can. Now try to press the peel perfectly flat on the table without tearing or squashing it. You can't! Where did it split? Keep the peel; you will use the idea all lesson long.

Video. Coming soon. Map projections compared: orange-peel demonstrations, globe gores, Mercator vs equal-area and the Robinson and Winkel tripel maps: search Smithsonian, NASA, Library of Congress, Memoria Press; Homeschool Pop (Alternate); Jay Foreman Map Men and National Geographic Kids (candidates, need vetting).

KEY TERMS

globe

A round model of the earth. It is the only map that shows sizes, shapes, distances and directions all correctly.

gore

A pointed strip of map, wide at the equator and narrow at the poles. Glued side by side on a ball, gores make a globe.

equal-area map

A map that keeps every land at its true size compared with the others, but bends or squashes shapes.

compromise map

A map that lets sizes and shapes each be a little wrong so that nothing is badly wrong, such as the Robinson or Winkel tripel map.

trade-off

Giving up some of one good thing to get more of another. Every flat map trades off sizes, shapes, distances or directions.

CORE IDEAS

The story. In 1492, in the German city of Nuremberg, a merchant named Martin Behaim, who had lived among the Portuguese navigators, worked with a painter named Georg Glockendon to finish a round model of the earth about 20 inches (51 cm) across. People later

nicknamed it the *Erdapfel*, the “earth apple.” It is the oldest globe of the earth that still survives, and you can see it today in the Germanisches Nationalmuseum in Nuremberg. It was finished just before news of Columbus’s first voyage reached Europe, so between Europe and Asia it shows only ocean and islands. There are no Americas on it at all.

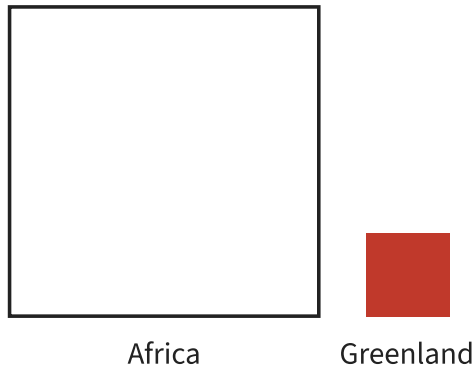
How it works. A **globe** is the only truly honest map. Every land is the right size and shape, every distance is in proportion, and every direction is true. But a globe has problems too. You can see only half of it at once, you cannot fold it into a pocket, and it would have to be enormous to show the streets of your town. So people want flat maps. And here is the trouble you found with your orange peel: a round skin cannot lie flat without tearing or stretching. Mapmakers solved one part of the problem with **gores**, pointed strips printed flat and then glued onto a ball, as Waldseemüller did in 1507. For a flat wall map, they must choose what to stretch.

The big idea. Every flat map makes a **trade-off**. Mercator’s map (1569) keeps shapes and directions true in every small place, so sailors can steer by it, but it swells lands near the poles. An **equal-area map** keeps every land at its true size compared with the others, but it squashes and bends shapes; the oval map drawn by Karl Mollweide in 1805 is one well-known example. A **compromise map** lets everything be a little wrong so that nothing is badly wrong; Arthur Robinson designed one in 1963, and National Geographic used it for its world maps from 1988 until it switched to another compromise, the Winkel tripel, in 1998. An interrupted map, like J. Paul Goode’s of 1923, cuts the oceans open like a peeled orange so that the lands keep good sizes and shapes.

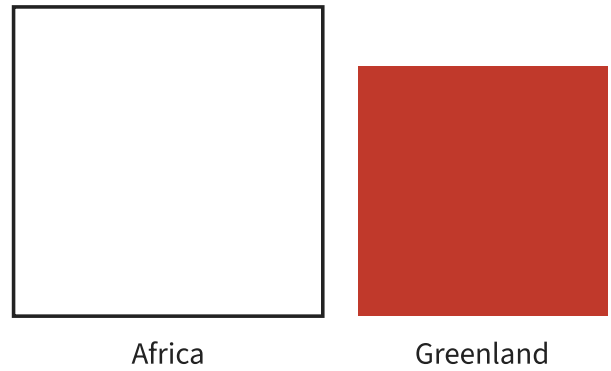
A debate worth weighing. In 1973 a German historian named Arno Peters made headlines with an equal-area world map. He said the Mercator map made the lands near the equator, much of Africa, South America and southern Asia, look smaller and less important than they are. Many schools and church groups took up his map. Many mapmakers answered that equal-area maps had been known for a long time (a Scottish minister, James Gall, had drawn almost the same one in 1855), that Peters’s map badly stretched the shapes of Africa and South America, and that the real fault was using a sailor’s map for every job. Both sides agreed on one thing: you should know what your map does to the world.

On the map. Put Greenland and Africa side by side in three views. On a globe and on an equal-area map, Africa is about 14 times bigger than Greenland. On a Mercator map Greenland looks nearly as big as Africa. On a compromise map, Greenland is still too big, but not by nearly as much. So a wise geographer chooses the map for the job: Mercator for steering a compass course, an equal-area map for comparing sizes of countries or forests or farmland, a compromise map for a classroom wall, and, when you need the whole truth, a globe.

True sizes (globe or equal-area)



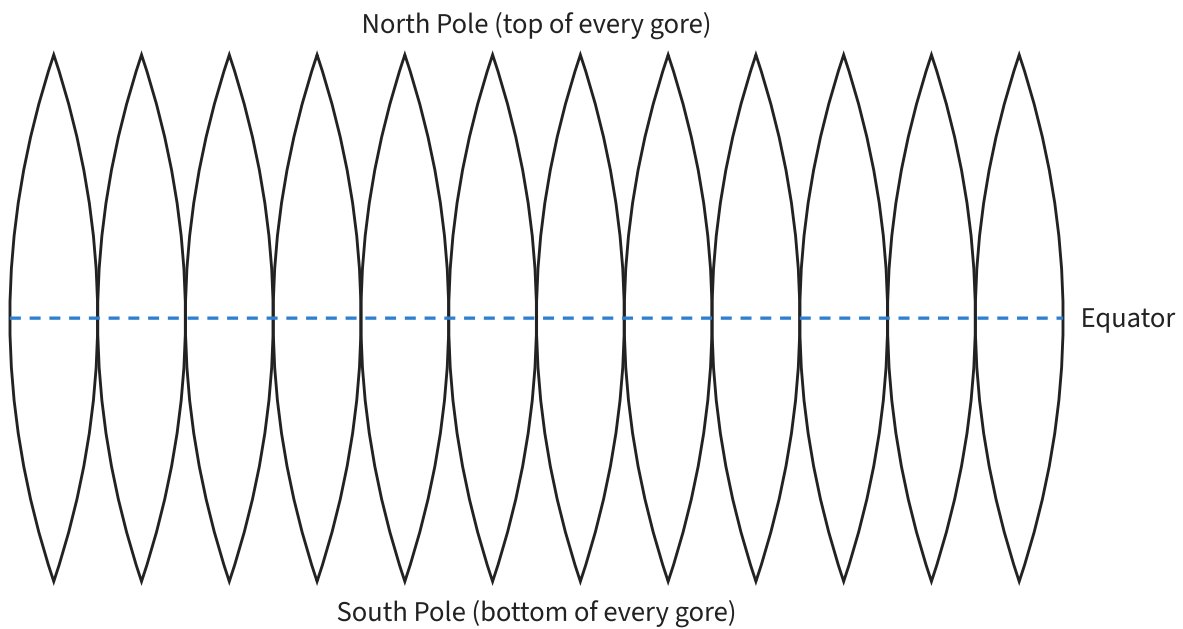
How they look on Mercator



Africa is about 14 times bigger than Greenland.

On a Mercator map, Greenland looks nearly as big.

Greenland and Africa in true size (globe or equal-area map) and as they look on a Mercator map.



12 gores, each 2 in wide at the equator and 12 in long, for a ball 24 in around

Globe gores. Twelve pointed strips cover a ball; between the strips are gaps that a flat map would have to stretch to fill.

PICTURE STUDY



The Erdapfel (Behaim Globe), Martin Behaim, with the painter Georg Glockendon, 1490-1492 · Painted map on a hollow ball, about 20 inches (51 cm) across, set in metal rings · Germanisches Nationalmuseum, Nuremberg, Germany

Martin Behaim was a merchant from Nuremberg who had lived in Portugal and said he had sailed on a Portuguese voyage along the coast of Africa. Back home, the city leaders asked him to help make a globe. The painter Georg Glockendon painted the map, with kings on thrones, flags, ships and long notes about the lands and their goods.

The globe shows the world exactly as learned Europeans pictured it in 1492, the year Columbus sailed. Ptolemy's stretched Asia reaches far around the back of the globe, and only a fairly narrow ocean, dotted with islands, separates Europe from the coast of Asia.

Look closely

- Look for the Americas. Why are they not there?
- Find the ocean west of Europe. How wide does it look compared with the real Atlantic and Pacific together?
- Look at the little pictures on the lands: kings, flags and animals. Why would a mapmaker add them?
- Look at the rings around the globe. What might they be for?

Talk about it

1. How would this globe have encouraged someone like Columbus?
2. What can a globe show better than any flat map? What can a flat map do better than a globe?
3. If you made a globe of the world today, what would you add that Behaim could not?

Safety first. An adult should start any knife cut in the orange. Use child-safe scissors for the gores, and wash the orange and your hands before eating the fruit.

PROJECT: THE PROJECTION PEEL

This is the unit's main project. You will draw lands on an orange and peel it flat, cover a ball with paper gores, and wrap a paper tube around the ball to see how a Mercator map is made. By the end you will know with your own hands why every flat map must stretch something.

You will need

- A large orange and a washable fine-tip marker
- A smooth ball (a playground ball or small beach ball) and a flexible tape measure or a piece of string and a ruler
- Several sheets of plain paper, tape, scissors and colored pencils
- A globe or a printed picture of a globe to copy from

Steps

1. Orange: draw an equator around the middle, and then, copying from a globe, draw a rough Africa across the equator and a rough Greenland near the top. Draw a small square grid on Africa.
2. Ask an adult to score the peel from top to bottom in 8 long strips. Peel it carefully and press it flat on paper. Trace around it. Where did it split? Did Greenland or Africa get stretched or torn more?
3. Gores: measure around the middle of your ball. Divide by 12 to get each gore's width at the equator, and divide the distance around by 2 to get each gore's length from pole to pole.
4. On paper (tape two sheets end to end if needed), draw 12 pointed gores of that width and length, touching at their widest points along an equator line. Cut them out and tape them onto the ball one by one, all meeting at the poles. Notice the small wrinkles and gaps.
5. Mercator tube: roll a sheet of paper into a tube that just touches the ball all the way around its equator. Look at how far the paper is from the ball near the top and bottom. That gap is why Mercator had to stretch the north and south.
6. Make a three-part poster: "Globe," "Mercator" and "Equal-area," with Greenland and Africa drawn in each, and the true sizes written below (Greenland about 836,000 sq mi; Africa about 11.7 million sq mi).

Tips

- Score the orange peel only through the skin, not deep into the fruit, and it will lift off in clean strips.
- Draw the gores with a ruler for the center line and curve the sides gently by hand; they do not need to be perfect to teach the lesson.

Check your work

- I can show where my orange peel tore or stretched and explain why.
- I worked out the width and length of my gores from the size of my ball.
- My poster shows Greenland and Africa truly on the globe and equal-area panels and stretched on the Mercator panel.

MAP NOTEBOOK

1. Trace your flattened orange peel and label which parts tore and which stretched.
2. Make a chart with four rows (globe, Mercator, equal-area, compromise) and two columns (keeps true / gives up).
3. Stretch a string on a globe between New York and Tokyo along the shortest path. Sketch where it goes, then sketch how that same path would look on a Mercator map.

From history. Stretch a string tight across a globe from New York to Tokyo, and it does not run straight west across the Pacific as it seems to on a flat map. It curves far north, passing near Alaska. That tight string marks a great circle, the shortest path across the round earth, and airplanes fly close to such paths to save fuel and time. On a Mercator map the same route looks like a long curve bulging toward the pole, another reminder that each flat map shows the world in its own way.

WORKED EXAMPLES

Example 1. A ball measures 24 inches around its middle. You want to cover it with 12 gores. How wide is each gore at the equator, and how long is each gore from pole to pole?

(Use the map or drawing “12 gores, each 2 inches wide and 12 inches long, cover a ball 24 inches around.” shown earlier in this lesson.)

1. The 12 gores share the 24 inches around the equator: $24 \div 12 = 2$ inches wide.
2. A gore runs from the North Pole to the South Pole, which is halfway around the ball:
 $24 \div 2 = 12$ inches long.

Answer: Each gore is 2 inches wide at the equator and 12 inches long.

Example 2. On an equal-area map, 1 square inch stands for 1 million square miles. Africa covers about 11.7 million square miles and Greenland about 0.84 million. How many square inches does each take up on the map? How many times bigger is Africa?

(Use the map or drawing “True sizes: Africa is about 14 times bigger than Greenland.” shown earlier in this lesson.)

1. Africa: $11.7 \text{ million} \div 1 \text{ million} = 11.7$ square inches.
2. Greenland: $0.84 \text{ million} \div 1 \text{ million} = 0.84$ square inch, a little less than one square inch.
3. Compare: $11.7 \div 0.84 \approx 14$.

Answer: Africa takes up about 11.7 square inches and Greenland about 0.84 square inch. Africa is about 14 times bigger, and an equal-area map shows exactly that.

PRACTICE

1. **EASY** What is a map projection, and why does every flat map need one?
2. **EASY** What is the oldest globe of the earth that still survives, who made it, and where is it kept?
3. **MEDIUM** Which kind of map would you choose (a) to steer a ship on a steady compass course, (b) to compare the sizes of Brazil and Greenland?
4. **MEDIUM** A ball is 30 inches around. How wide and how long is each gore if you use 10 gores?
5. **MEDIUM** Look at the Greenland and Africa squares. On the true-size side, about how many Greenlands fit in Africa? On the Mercator side, does Greenland look bigger or smaller than that suggests?
(Use the map or drawing “Compare the two sides.” shown earlier in this lesson.)
6. **HARD** On an equal-area map where 1 square inch stands for 1 million square miles, how many square inches would South America (about 6.9 million square miles) and the United States (about 3.8 million square miles) cover?
7. **HARD** In two or three sentences, use an orange peel to explain why no flat map can be true in every way.
8. **CHALLENGE** Name what each of these keeps true and what it gives up: a Mercator map, an equal-area map, and a compromise map such as the Robinson.

COMMON MISTAKES

- Thinking there is one “correct” flat map. Every flat map trades something away; the best one depends on the job.
- Thinking an equal-area map is right in every way. It keeps sizes true but bends shapes, especially near the edges.
- Forgetting that a globe is a map too, and the most truthful one, even though it cannot show the whole world at once.

Make it a game · Pick the Map. Write job cards such as “sail from Lisbon to Brazil on one compass course,” “show how big each country’s farmland is,” “hang a world map on the classroom wall,” “find the shortest flight from Chicago to Beijing,” and “compare Greenland and Australia.” Lay out four cards: Globe, Mercator, Equal-area, Compromise. Draw a job card and place it on the best map within ten seconds, then give a reason. A right answer with a good reason scores 2 points.

Scripture. “A false balance is abomination to the LORD: but a just weight is his delight.” (Proverbs 11:1, KJV)

God loves honest measures. No flat map can be perfect, but an honest mapmaker and an honest map reader will say plainly what the map stretches and what it keeps true.

Practice answers

1. A projection is a way of drawing the round earth on a flat sheet. Every flat map needs one because a round surface cannot be laid flat without stretching or tearing.
2. The Erdapfel, finished in 1492 by Martin Behaim with the painter Georg Glockendon. It is in the Germanisches Nationalmuseum in Nuremberg, Germany.
3. (a) A Mercator map, because a steady compass course is a straight line on it. (b) An equal-area map (or a globe), because it keeps sizes true.
4. Width: $30 \div 10 = 3$ inches at the equator. Length: $30 \div 2 = 15$ inches from pole to pole.
5. About 14 Greenlands fit in Africa. On the Mercator side, Greenland looks far bigger, nearly as big as Africa.
6. South America about 6.9 square inches; the United States about 3.8 square inches.
7. When you peel an orange and press the peel flat, it tears or stretches, because a curved skin does not fit on a flat table. The earth’s surface is curved the same way. So every flat map must stretch, squash or cut the earth somewhere, and the mapmaker chooses where.
8. Mercator keeps shapes of small areas and compass directions true but makes lands near the poles far too big. An equal-area map keeps sizes true but bends and squashes shapes. A compromise map keeps nothing perfectly true but keeps sizes and shapes only a little wrong, so the whole world looks about right.

UNIT 4 REVIEW

Answer each question. Show your work for calculations and use complete sentences for explanations. Use the true areas given in the questions. The review is worth 50 points.

1. (5 pts) Who was Claudius Ptolemy, where did he live, and what did his *Geography* contain?
2. (5 pts) Name two mistakes in Ptolemy's picture of the world, and tell how one of them affected explorers.
3. (5 pts) Rome is at about 42°N and Alexandria at about 31°N. About how far apart are they from north to south? (1° of latitude $\approx$ 69 miles.)
4. (5 pts) Who made the 1507 map that first used the name America, after whom was the name chosen, and on which continent of the map does the name appear?
5. (5 pts) The Waldseemüller map has 12 sheets in 3 rows of 4. Each sheet is about 18 inches tall and 24 inches wide. How tall and wide is the whole map in feet? Where is the only surviving copy?
6. (5 pts) What problem was Mercator's 1569 map made to solve for sailors? Use the words *bearing* and *rhumb line*.
7. (5 pts) A square of land 50 miles on each side lies at 60°N. Mercator draws everything there 2 times wider and 2 times taller. What area does the square look like it has, and how many times its true area is that?
8. (5 pts) Africa covers about 11.7 million square miles and Greenland about 0.84 million. About how many times bigger is Africa? Why do they look almost the same size on a Mercator map?
9. (5 pts) A ball is 36 inches around. You cover it with 12 gores. How wide is each gore at the equator, and how long from pole to pole?
10. (5 pts) Explain why no flat map can be true in every way, and tell which map you would choose to compare the sizes of countries and why.

UNIT PROJECT: THREE WAYS TO SEE THE WORLD

Make a poster or a folder that shows the world three ways: as a globe, on a Mercator map and on an equal-area map. Include your flattened orange-peel tracing, your paper gores (or a photo of your gore-covered ball), and your hand-drawn Mercator grid with its rhumb line and measured bearing. In each of the three views, draw Greenland and Africa and write their true areas beneath. Finish with a paragraph that tells the story of one mapmaker from this unit (Ptolemy, Waldseemüller or Mercator) and explains what every map gives up and how to choose the right one.

- **Accuracy:** Greenland and Africa are shown truly on the globe and equal-area views and stretched on the Mercator view; true areas and the 14-to-1 comparison are correct; the Mercator grid spacing grows toward the pole.
- **Hands-on work:** The orange peel, gores and rhumb-line grid are included, labeled and measured, with the gore width and length worked out from the ball's size.

- **Explanation:** The paragraph tells a real mapmaker's story correctly and explains clearly why every flat map makes a trade-off and which map fits which job.
- **Care:** The work is neat, colorful and easy to read, with titles, labels and a compass rose.

Answer key

1. A Greek-speaking scholar of Alexandria, Egypt, who wrote the *Geography* about AD 150. It listed about 8,000 places with their latitude and longitude and gave instructions for drawing a map of the world.
2. Any two: he made the earth too small; he stretched Europe and Asia too far east (180° instead of about 140°); he closed the Indian Ocean with land. The small earth and wide Asia made the ocean west of Spain look narrow, which encouraged Columbus; the closed Indian Ocean was proved wrong by Dias in 1488.
3. $42 - 31 = 11^\circ$. $11 \times 69 = 759$ miles (about 1,220 km).
4. Martin Waldseemüller, working with Matthias Ringmann in Saint-Dié. The name honored Amerigo Vespucci, and it was printed on South America.
5. $3 \times 18 = 54$ inches = $4\frac{1}{2}$ feet tall; $4 \times 24 = 96$ inches = 8 feet wide. The only copy is at the Library of Congress in Washington, D.C.
6. Sailors steer by compass bearing. A course that keeps the same bearing is a rhumb line, which curves on a globe. Mercator's map makes every rhumb line straight, so a navigator can draw a line from port to port with a ruler, measure its bearing and steer it.
7. It looks 100 by 100 miles = 10,000 square miles. Its true area is $50 \times 50 = 2,500$ square miles, so it looks 4 times too big.
8. $11.7 \div 0.84 \approx 14$ times. Greenland lies far north, where Mercator's map stretches lands both ways, while Africa lies across the equator, where there is little stretching.
9. $36 \div 12 = 3$ inches wide; $36 \div 2 = 18$ inches long.
10. A curved surface, like an orange peel, cannot be laid flat without tearing or stretching, so every flat map gives up something: sizes, shapes, distances or directions. To compare sizes I would choose an equal-area map (or a globe), because it keeps every land at its true size.

CAPTAIN COOK AND THE PACIFIC

The Pacific is the largest ocean God made, bigger than all the land on earth put together. Polynesian voyagers had crossed it in canoes long before, but in 1768 European maps still showed it with huge blank spaces and a guessed-at southern continent. Over the next eleven years one man, James Cook, the son of a Yorkshire farm worker, filled in much of that blank. In three great voyages he sailed to Tahiti to watch Venus cross the sun, charted New Zealand and the east coast of Australia, crossed the Antarctic Circle, found the Hawaiian Islands and pushed through the Bering Strait to the Arctic ice.

In this unit you will watch the transit of Venus at Point Venus, take bearings to headlands with Cook's running survey, test which foods fight scurvy, and follow Cook to Kealakekua Bay, where he died on February 14, 1779. You will practice latitude, bearings, map scale and the time-and-longitude rule from Unit 3. Most of all you will learn to judge an explorer honestly: Cook's patience, courage and care for his men were real, and so were the shootings, the claim to Australia without its peoples' consent, and the force he used when he grew impatient. Truth tells both.

BEFORE YOU BEGIN

- Can read latitude and longitude in degrees and minutes and knows that one degree of latitude is 60 nautical miles (Units 2–3)
- Knows that each hour of time difference equals 15 degrees of longitude (Unit 3)
- Can measure an angle with a protractor and use a map scale
- Can multiply and divide whole numbers to find speed, time and distance

MASTERY CHECKLIST

- I can explain why Cook sailed to Tahiti in 1769 and how a transit of Venus helped measure the distance to the sun.
- I can fix the position of a headland from two bearings, as Cook did in his running survey.
- I can explain what causes scurvy and how fresh food, cleanliness and rest kept Cook's crews alive.
- I can trace all three of Cook's voyages on a map and find distances north and south using latitude.
- I can tell the story of Cook's death in Hawaii fairly, from both sides.
- I can judge Cook honestly, naming both his skill and courage and the real wrongs done on his voyages.

OPTIONAL BOOKS AND RESOURCES

- **Royal Museums Greenwich** (<https://www.rmg.co.uk/>): Free to browse. The National Maritime Museum holds William Hodges's paintings from Cook's second voyage,

Nathaniel Dance's portrait of Cook, and the K1 timekeeper. Search the collections for "Hodges" or "Cook."

- **Project Gutenberg** (<https://www.gutenberg.org/>): Free. Search for "Captain Cook's Journal" to find Cook's own journal of his first voyage. A parent can choose short passages to read aloud, such as the day of the transit (June 3, 1769) or the grounding on the reef (June 11, 1770).

5.1 THE TRANSIT OF VENUS ★

OBJECTIVES

- Tell the story of James Cook's voyage in the *Endeavour* to Tahiti to watch the transit of Venus on June 3, 1769.
- Explain in simple words why observers far apart on the earth could use a transit of Venus to find the distance to the sun.
- Locate Tahiti by latitude and longitude, trace the *Endeavour's* route around Cape Horn, and change Tahiti time into Greenwich time.

Warm-up. Hold your thumb up at arm's length and line it up with a door frame or a picture on the far wall. Close your left eye, then open it and close your right eye. Switch back and forth. Your thumb seems to jump! Now bring your thumb close to your nose and try again. Does it jump more or less? Talk about it: your two eyes see from two different places. Astronomers in 1769 used the very same trick, but their two "eyes" were thousands of miles apart.

Watch. *What is the transit of Venus?* (Physics World, 3:03).

<https://www.youtube.com/watch?v=i5OCYKy5uYY>

With the big idea: watch to see how timing Venus as it crossed the Sun's face let astronomers work out how far the Earth is from the Sun, which is why Cook was sent to Tahiti.

Note: Captions were not available to check; preview it first. A university scientist explains the science in about 3 minutes. The video explains the science of the transit. It probably does not tell the story of Cook, the *Endeavour* or Tahiti in 1769.

KEY TERMS

transit of Venus

The rare time when the planet Venus passes directly between the earth and the sun, so it looks like a small black dot crossing the sun's face.

parallax

The way a near object seems to shift against a faraway background when you look at it from two different places, like your thumb jumping when you switch eyes.

observatory

A place set up with telescopes, clocks and instruments for watching the sky. Cook's men built a small one on Tahiti.

Royal Society

Britain's society of scientists, founded in 1660. It asked the king and the Navy to send Cook to the Pacific.

Polynesia

The great triangle of Pacific islands between Hawaii, New Zealand and Easter Island, settled long ago by skilled canoe voyagers.

CORE IDEAS

The story. In August 1768 a small, sturdy ship named the *Endeavour* sailed out of Plymouth, England. She had been built in Whitby to carry coal, and her commander, Lieutenant James Cook, had learned the sea on just such coal ships. Cook was the son of a Yorkshire farm worker. He had taught himself mathematics and astronomy, and he had made such careful charts of the coast of Newfoundland that the Navy trusted him with a great task. The Royal Society wanted someone in the middle of the Pacific Ocean on one particular day: June 3, 1769. On that day the planet Venus would cross the face of the sun, and it would not happen again for more than a hundred years.

How it worked. Long before, the astronomer Edmond Halley had explained what such a crossing, called a **transit**, could teach. If people watched it from places far apart on the earth, each would see Venus take a slightly different path across the sun, the way your thumb jumps when you switch eyes. That shift is called **parallax**. By timing exactly when Venus touched the edge of the sun and when it left, and comparing the times from different places, astronomers could work out the distance from the earth to the sun. Transits of Venus come in pairs eight years apart, with more than a century between pairs. The first of the pair came in 1761. The 1769 transit was the last chance in anyone's lifetime, so observers went to Hudson Bay in Canada, to northern Norway and, with Cook, to Tahiti.

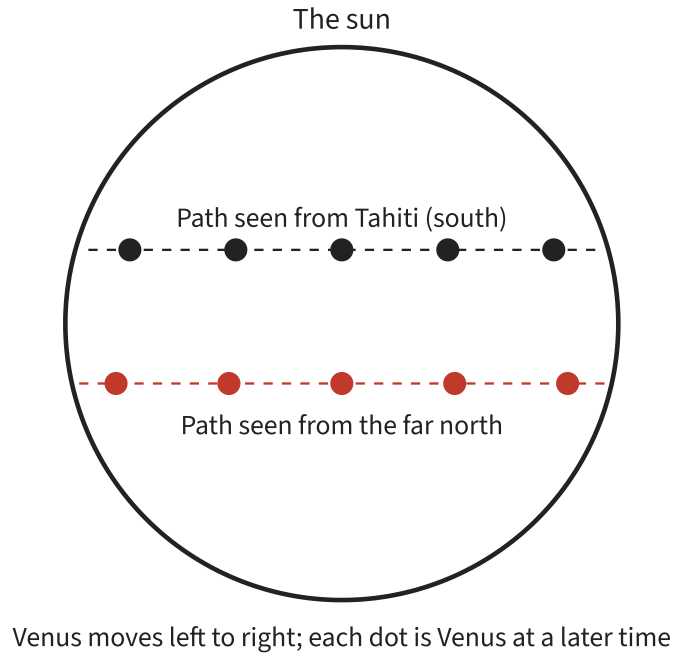
The voyage. The *Endeavour* sailed south through the Atlantic, stopped at Madeira and Rio de Janeiro, and rounded stormy Cape Horn. She anchored in Matavai Bay, Tahiti, on April 13, 1769, after about seven and a half months at sea. The Tahitians traded breadfruit, coconuts and pigs, and many were friendly. Yet there were troubles too. In the first days a Tahitian man who snatched a musket from a guard was shot dead, which grieved Cook. Later someone carried off the astronomical quadrant from the little fort, and Joseph Banks, the ship's naturalist, and Charles Green, the astronomer, chased over the hills to get it back. Without it the whole voyage would have been wasted.

The big day. June 3 dawned without a cloud. On a point of land the sailors named Point Venus, Cook, Green and the naturalist Daniel Solander watched through their telescopes for about six hours as the black dot of Venus crossed the sun. But at the edges, Venus seemed to cling to the sun's rim like a drop of ink, a blur later called the "black drop." The three men's timings did not agree as closely as they had hoped. Even so, when the times from Tahiti and many other stations were put together, astronomers found the sun to be roughly 93 million miles (150 million km) away, close to what we know today.

On the map. Point Venus lies at about 17°30' S, 149°30' W, so Tahiti is about 150 degrees west of Greenwich. From Unit 3 you know that each hour of time difference is 15 degrees of longitude, so Tahiti's clocks run about 10 hours behind Greenwich. Charles Green also used the stars and the moon to fix Tahiti's position carefully, so later sailors could find it again. After the transit Cook opened his secret orders: search the southern ocean for a great

unknown continent. A Tahitian navigator and priest named Tupaia, from the nearby island of Raiatea, sailed with him and drew a chart of dozens of islands he knew. The Polynesians had crossed this ocean in canoes long before any European ship arrived.

The heavens and the earth. It is a wonder that a ship sailed nearly halfway around the world to watch a dot cross the sun for an afternoon. Cook's voyage shows how measuring the heavens helps us measure the earth. The same sky that tells the sailor his latitude, and the same clocks and stars that tell his longitude, helped men measure the distance to the sun itself. As the psalmist wrote, "The heavens declare the glory of God."



Observers far apart see Venus cross the sun on slightly different paths. Timing the crossing from each place lets astronomers work out the distance to the sun.



The Endeavour's route to Tahiti, August 1768 to April 1769.

PICTURE STUDY



Tahiti Revisited, William Hodges, 1776 · Oil on canvas · National Maritime Museum, Greenwich, London

William Hodges was the artist Cook took on his second voyage (1772–1775), when the ships returned to Tahiti. Back in London, Hodges painted large oil paintings for the Admiralty from the sketches he made on the voyage. In *Tahiti Revisited* he shows the island Cook first reached in 1769: steep green mountains, palm trees, warm light and the calm water of a bay.

Hodges tried to paint the strong, bright light of the tropics, which looked very different from the gray skies of England. Some people in London thought his colors too bold. Today his paintings are among the first pictures Europeans ever saw of the South Pacific.

Look closely

- Find the mountains. How steep are they? What does that tell you about how the island was formed?
- Look at the light. Where is the sun? How is this light different from a cloudy day at home?
- Find the people and any buildings or carvings. What are the people doing?
- Find the palm trees. What else would you expect to grow on an island at 17° S?

Talk about it

1. If you had sailed seven months to reach this island, what would you have wanted first?
2. Hodges painted from sketches after he got home. What might he have changed or made more beautiful? Why should we look at old paintings carefully?
3. Why do you think the Royal Society chose a tropical island rather than a cold, cloudy place to watch the transit?

Safety first. Never look directly at the sun, with or without binoculars or a telescope. It can blind you in seconds. If you use a lamp in this project, choose a cool LED bulb, and have an adult help.

PROJECT: MODEL TRANSIT AND THE TWO-EYED EARTH

You will act out a transit of Venus with a lamp and a coin, time it with a partner, and then use parallax to see why Cook had to go so far away to help measure the sun.

You will need

- A lamp with a round shade, or a large paper plate taped to the wall to be the sun
- A coin or a small black paper circle on a thin stick or straw to be Venus
- Two watches, phones or a kitchen timer for timing
- A yardstick or tape measure
- Masking tape, pencil and your map notebook

Steps

1. Tape a large paper plate to the wall at eye height. This is the sun.
2. Put two pieces of tape on the floor about 6 feet (2 m) from the wall and about 3 feet (1 m) apart. One is “Hudson Bay” (north) and one is “Tahiti” (south).
3. Your helper holds the coin on its stick about halfway between the tape marks and the plate, and walks it slowly from left to right across the front of the plate at a steady pace.

4. Stand on the “Tahiti” mark and close one eye. Start your timer when the coin first touches the edge of the plate and stop it when the coin leaves the other edge. Write the time.
5. Repeat from the “Hudson Bay” mark, standing on a stool or crouching low so your eye is at a different height. Write the time.
6. Compare the two times. Did the coin seem to cross a higher or lower part of the plate? Did the crossing take longer from one place?
7. Now move the two marks closer together, only 6 inches apart, and repeat. Does the difference get smaller?
8. In your notebook, draw the plate with the two paths of the coin, and write one sentence explaining why observers needed to be far apart.

Tips

- Keep the coin moving at the same speed every time, or your times will not be fair. Practice the walk first.
- Notice how hard it is to see the exact moment of “touch.” Cook and Green had the same trouble with the black drop.
- Never look at the real sun, through a telescope or without one. Astronomers use special filters, and even then only with expert help.

Check your work

- I can explain what a transit of Venus is.
- I can show that two observers in different places see a slightly different path.
- I can explain why the Royal Society sent observers to places far apart, including Tahiti.

MAP NOTEBOOK

1. Draw the sun as a big circle and Venus as a small black dot crossing it. Add the “black drop” at the edge and label it.
2. On a simple world outline, mark Plymouth, Rio de Janeiro, Cape Horn and Tahiti, and draw the *Endeavour*’s route with arrows. Write the dates August 1768 and April 13, 1769.
3. Draw Point Venus with the little fort, a telescope and a tent. Label the latitude and longitude: about 17°30’ S, 149°30’ W.

From history. Venus has crossed the sun only twice since the pair of 1761 and 1769: in 1874 and 1882, and again in 2004 and 2012. Millions of people watched the 2012 transit through safe solar filters and on live video. The next transit of Venus will not come until December 2117. Point Venus on Tahiti still bears the name Cook’s crew gave it, and a lighthouse now stands near the spot where the observatory tents once stood.

WORKED EXAMPLES

Example 1. The *Endeavour* left Plymouth on August 26, 1768, and anchored at Tahiti on April 13, 1769. How many days was the voyage?

(Use the map or drawing “Follow the route as you count the months.” shown earlier in this lesson.)

1. Count the rest of August after the 26th: $31 - 26 = 5$ days.
2. Add the whole months: September 30, October 31, November 30, December 31, January 31, February 28 (1769 was not a leap year), March 31. That is 212 days.
3. Add 13 days of April.
4. Total: $5 + 212 + 13 = 230$ days.

Answer: 230 days, about seven and a half months.

Example 2. Tahiti is about 150° W of Greenwich. Suppose Cook saw Venus first touch the sun at 9:30 in the morning, Tahiti time. What time was it then at Greenwich, England?

1. Each hour of time difference is 15 degrees of longitude.
2. $150 \div 15 = 10$, so Tahiti is 10 hours different from Greenwich.
3. Tahiti is west of Greenwich. The sun reaches Greenwich first, so Greenwich clocks are 10 hours *ahead*.
4. 9:30 a.m. + 10 hours = 7:30 p.m.

Answer: 7:30 in the evening at Greenwich, on the same day.

PRACTICE

1. **EASY** What happened in the sky on June 3, 1769, and why did the Royal Society want it watched?
2. **EASY** Tahiti is at about 17° S, 150° W. Is it in the Northern or Southern Hemisphere? The Eastern or Western Hemisphere?
3. **EASY** Transits of Venus come in pairs eight years apart. The first of the pair was in 1761. In what year was the second?
4. **MEDIUM** Look at the map of the *Endeavour*'s route. Which cape did the ship sail around to enter the Pacific? In which direction did she sail from Rio de Janeiro to reach it?
(Use the map or drawing “The route to Tahiti.” shown earlier in this lesson.)
5. **MEDIUM** Plymouth is at about 50° N. Tahiti is at about 17° S. How many degrees of latitude lie between them? Using 60 nautical miles for each degree of latitude, how many nautical miles is that, going straight north and south?
6. **MEDIUM** It is noon at Greenwich. Tahiti is 10 hours behind Greenwich. What time is it at Tahiti?

7. **HARD** The sun is about 93 million miles away. If a jet airliner could fly there at 500 miles an hour without stopping, about how many hours would the trip take? About how many years is that?
8. **CHALLENGE** In two or three sentences, explain why astronomers had to watch the transit from places thousands of miles apart, not just from London.

COMMON MISTAKES

- Thinking Cook went to Tahiti to explore. The first reason was astronomy: to time the transit of Venus. The search for a southern continent came in his secret orders afterward.
- Getting the time difference backward. Places west of Greenwich are behind Greenwich time, so you add hours to get Greenwich time.
- Adding latitudes on the same side of the equator. You add only when one is north and one is south; if both are north (or both south), you subtract.

Make it a game • Black Drop Timing. One player slowly rolls a marble across a large paper circle on the table while two “astronomers” sit at opposite ends and each calls out “Touch!” when the marble first touches the circle and “Gone!” when it leaves. A third player with a stopwatch writes down both calls. Whoever’s times come closest to the stopwatch player’s own times scores a point. Swap jobs and play five rounds. Talk about why it is so hard to agree on the exact moment.

Scripture. “The heavens declare the glory of God; and the firmament sheweth his handywork.” (Psalm 19:1, KJV)

God set the planets in their courses so faithfully that Halley could predict a transit decades ahead. Cook and Green measured that order, and in measuring it they were reading the handiwork of the Creator.

Practice answers

1. The planet Venus crossed the face of the sun (a transit of Venus). Timing it from places far apart would help astronomers work out the distance from the earth to the sun.
2. Southern Hemisphere (S) and Western Hemisphere (W).
3. $1761 + 8 = 1769$.
4. Cape Horn, at the southern tip of South America. From Rio de Janeiro she sailed southwest (south and a bit west).
5. $50 + 17 = 67$ degrees (add, because they are on opposite sides of the equator). $67 \times 60 = 4,020$ nautical miles. The real voyage was much longer, because the ship also had to sail far west.
6. 2:00 a.m. (noon minus 10 hours), in the middle of the night.
7. $93,000,000 \div 500 = 186,000$ hours. $186,000 \div 24 = 7,750$ days. $7,750 \div 365$ is about 21 years.
8. Sample answer: Observers far apart see Venus cross the sun on slightly different paths and at slightly different times, like your thumb jumping when you look with one eye and then the

other. The farther apart they stand, the bigger the difference, and that difference is what lets astronomers calculate the distance to the sun. One place alone shows no shift at all.

5.2 MAPPING NEW ZEALAND AND AUSTRALIA

OBJECTIVES

- Tell how Cook sailed all the way around New Zealand (1769–1770) and up the east coast of Australia (1770), and name both what he did well and what he did wrong.
- Explain how a running survey works: taking bearings to the same point from two places and finding where the lines cross.
- Use bearings, map scale and latitude to find distances on a chart of New Zealand and eastern Australia.

Warm-up. Put a cup on the far side of the table. Stand at one corner and point a pencil straight at the cup. Have a helper lay a ruler along your pencil's line. Now walk to the other corner and do it again with a second ruler. Where do the two rulers cross? That is where the cup is. You just found a place without walking to it, the same way Cook found the headlands of New Zealand from his ship.

Watch. *James Cook's Journey to Australia - "Ends of the Earth"* (Drive Thru History with Dave Stotts, 4:45). <https://www.youtube.com/watch?v=A-STmZDEAtw>

After the story: watch Dave Stotts tell how Cook reached Australia's east coast, and listen for the places Cook named as he charted it.

Note: Captions were not available to check; preview it first. This is a clip from a TBN series on Christian history, so it may move on from Cook to the story of the gospel in Australia. It may say little about New Zealand, the Great Barrier Reef or how triangulation works.

Backup video. *19th April 1770: British explorer Captain James Cook first sights Australia from HMS Endeavour* (HistoryPod, 2:18). <https://www.youtube.com/watch?v=fx9hyaYIKXM>

With On the map: watch to follow the Endeavour from Point Hicks up the coast to Botany Bay, and find both places on your map. Note: Captions were not available to check; preview it first. It explains that the date in the ship's log may be one day off, because the crew had crossed the globe and 'skipped' a day on the calendar. The video gives the date of first sighting as 19 April 1770 but notes some sources say 20 April.

KEY TERMS

chart

A map made for sailors, showing coastlines, depths of water, rocks and harbors.

bearing

The compass direction from one place to another, often given in degrees clockwise from north (north 0°, east 90°, south 180°, west 270°).

triangulation

Finding where something is by measuring the directions to it from the two ends of a known line and drawing the triangle.

running survey

Charting a coast from a moving ship by taking bearings to headlands and hills from one spot after another along the way.

strait

A narrow stretch of sea joining two larger bodies of water, such as Cook Strait between New Zealand's two main islands.

CORE IDEAS

The story. After the transit of Venus, Cook sailed south from Tahiti looking for the great southern continent. He found only empty ocean, so he turned west. On October 6, 1769, a ship's boy named Nicholas Young sighted land from the masthead, and the headland is still called Young Nick's Head. This was New Zealand, which the Dutch sailor Abel Tasman had glimpsed in 1642. Tasman had seen only part of one coast, and some people thought it might be the edge of the southern continent. The first meetings with the Māori people at the bay Cook named Poverty Bay went badly: in several clashes, Cook's men shot and killed several Māori. Cook wrote in his journal that he knew kind-hearted people would blame him for it. Tupaia, the Tahitian navigator, could speak with the Māori because their languages were related, and after that he often helped the two peoples understand each other.

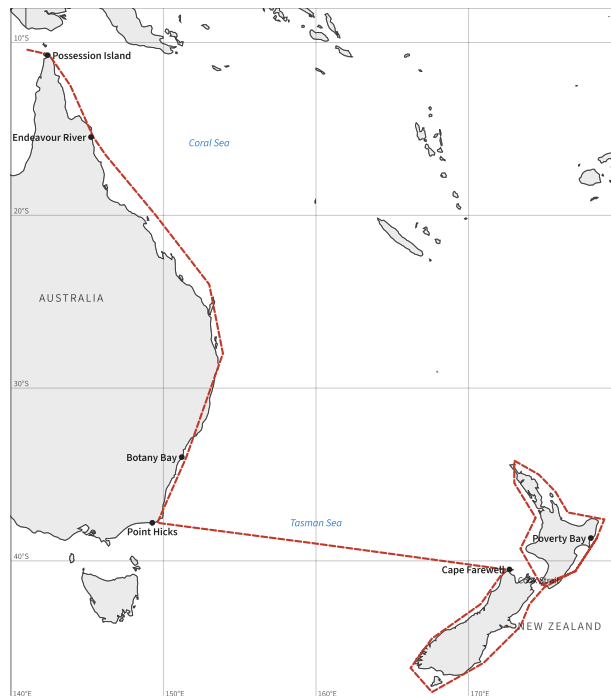
How they figured it out. Cook had learned surveying in Canada, charting the St. Lawrence River and the coast of Newfoundland. Now he used a **running survey**. As the *Endeavour* sailed along the coast, he stopped often to take compass **bearings** to a headland, a hill or an island. Then the ship sailed on a measured distance, found with the log line, and he took a second bearing to the same point. On his chart he drew the ship's two positions and the two bearing lines. Where the lines crossed was the headland. This is **triangulation**. At noon he measured the sun's height for latitude, and the astronomer Charles Green used the moon and stars to work out longitude. Point by point, the coastline appeared on paper.

The big idea. In about six months, from October 1769 to March 1770, Cook sailed all the way around both main islands of New Zealand, charting about 2,400 miles of coast. He found the strait between the islands that now bears his name, and he proved that New Zealand was islands, not the corner of a continent. His chart was so good that sailors used it for many years. It had only a few large mistakes: he drew Banks Peninsula as an island, and he drew Stewart Island as a peninsula joined to the South Island. Even the best mapmakers can be fooled by weather, distance and fog.

Australia. Next Cook sailed west across the Tasman Sea. On April 19, 1770, Lieutenant Zachary Hicks sighted the southeast corner of Australia, which the Dutch called New Holland. Cook charted north along the coast and landed at a bay full of new plants, so he named it Botany Bay. Two men of the Gweagal people stood on the rocks to stop the landing, and Cook's men fired small shot at them, wounding one. Farther north, on the night of June 11, the *Endeavour* struck the Great Barrier Reef. The crew threw cannons and heavy stores overboard, pulled her off, and spent about seven weeks mending her at a river they named

the Endeavour River. There the local Guugu Yimithirr people traded and quarreled with the sailors, and the British first saw kangaroos. On August 22, 1770, on Possession Island near the northern tip, Cook claimed the whole east coast for King George III. His instructions had said to take possession only with the consent of the native people, and he did not ask it. The land was already home to many peoples, and that claim became the start of British settlement there.

On the map. Botany Bay lies at about 34° S, and Possession Island at about $10^{\circ}44'$ S. Cook charted about 2,000 miles of Australia's east coast between them, then sailed through Torres Strait, showing that New Guinea and Australia are separate. God made the coasts of the world, every bay and reef. Cook's gift was patience: point after point, bearing after bearing, he put them on paper truly, so that sailors after him could sail safely.



The Endeavour's route around New Zealand and up the east coast of Australia, October 1769 to August 1770.

PICTURE STUDY



A View of Cape Stephens in Cook's Strait with Waterspout, William Hodges, 1776 · Oil on canvas · National Maritime Museum, Greenwich, London (Ministry of Defence Art Collection)

On Cook's second voyage, in May 1773, the *Resolution* was sailing through Cook Strait, the passage Cook had found and charted in 1770, when the crew saw several waterspouts. A waterspout is a spinning column of wind and spray, like a small tornado over water. William Hodges, the voyage artist, later turned his sketches into this dramatic painting for the Admiralty.

Hodges wanted people in London to feel the danger and grandeur of the sea at the far side of the world. The rocky cape, the dark clouds and the tiny ship all help tell that story.

Look closely

- Find the waterspout. Where does it touch the sea, and where does it reach the clouds?
- Find the ship. Which way is the wind pushing her? How can you tell?
- Look at the coast. Would you want to sail close to it in a storm? Why or why not?
- Where is the light coming from? What feeling does the painting give you?

Talk about it

1. Cook charted this strait three years before this storm. How would a good chart help a captain in weather like this?
2. Why might a painter make a storm look even wilder than it was?
3. What can a painting tell us about a place that a chart cannot? What can a chart tell us that a painting cannot?

PROJECT: CHART A COASTLINE BY TRIANGULATION FROM A TOY BOAT

You will make a pretend coast on the floor, sail a toy boat along a straight line beside it, take bearings from two places, and draw a true chart of the coast without ever touching it, just as Cook did.

You will need

- A long rope, string or masking tape to make a wiggly coastline on the floor
- Five or six small objects for headlands (cups, blocks or toy trees)
- A toy boat
- A yardstick or tape measure
- A protractor, a large sheet of paper and a ruler
- A straw or pencil to sight with, and masking tape

Steps

1. Lay the rope on the floor in a wiggly line about 8 feet long to be the coast. Put a cup or block on each point that sticks out. These are your headlands. Number them 1, 2, 3 and so on.
2. About 3 feet from the coast, lay a yardstick parallel to the coast. This is the ship's course, your baseline. Mark station A at one end and station B at the other end, 3 feet apart. Choose one direction along the floor to call north and put a paper arrow on the floor.
3. Set the toy boat at station A. Put the protractor flat on the floor with its center on the boat and its straight edge pointing north. Sight along a straw from the boat to headland 1 and read the angle from north. Write it down. Do the same for every headland.
4. Sail the boat to station B and take bearings to the same headlands again.
5. On your paper, draw the baseline to scale (for example, 1 inch on paper = 6 inches on the floor, so 3 feet becomes 6 inches). Mark A and B and draw a north arrow.
6. From A, use the protractor to draw a light line at the bearing for headland 1. From B, draw the line for headland 1. Where the lines cross, put a dot and label it 1. Do the same for each headland.
7. Join the dots with a smooth line to draw your coast. Add a scale bar, a compass rose, a title and your name as surveyor.
8. Check your work: measure the real distance on the floor from the baseline to one headland and compare it to your chart, using your scale.

Tips

- Keep the protractor's straight edge lined up with north every time, or all your bearings will be twisted.
- If two lines meet at a very thin angle, the dot is hard to place. Cook had the same trouble. Move your baseline or make it longer.
- Measure each bearing twice. Surveyors never trust a single sighting.

Check your work

- I can take a bearing from north with a protractor.
- I can find a headland where two bearing lines cross.
- My chart has a scale bar, north arrow and labels, and matches the real coast fairly closely.

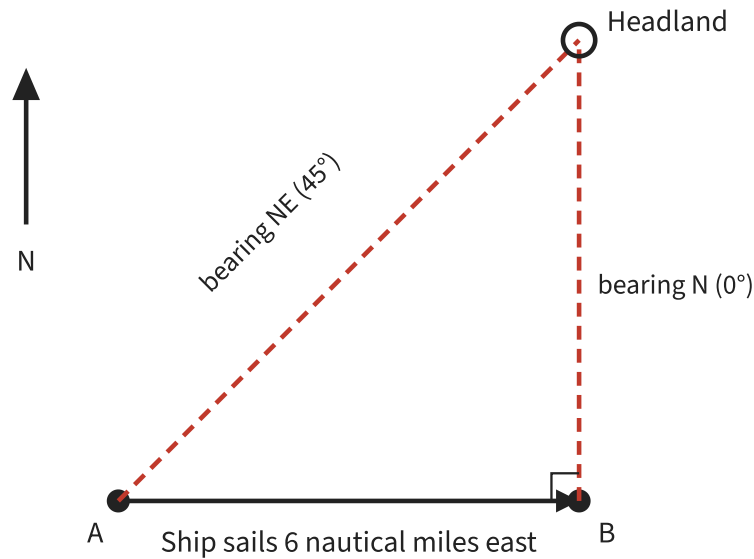
MAP NOTEBOOK

1. Trace or sketch New Zealand's two main islands. Label Cook Strait, Young Nick's Head, Poverty Bay, Banks Peninsula and Stewart Island. Draw Cook's two mistakes in a different color.
2. Sketch Australia's east coast and mark Point Hicks, Botany Bay, the Great Barrier Reef, the Endeavour River and Possession Island with their dates.
3. Draw the triangulation diagram: a ship at A and at B, a headland, and two bearing lines crossing. Label the baseline with its length.

From history. Cook learned his surveying craft in Canada. In 1758 he met an army surveyor named Samuel Holland on the shore at Louisbourg, watched him work with a plane table, and asked to be taught. The next year Cook helped chart the dangerous St. Lawrence River so the British fleet could sail up to Quebec, and from 1763 to 1767 he charted the coasts of Newfoundland. By the time he reached New Zealand, he was one of the best marine surveyors in the world.

WORKED EXAMPLES

Example 1. Cook's ship is at station A. A headland bears northeast (45°). The ship sails 6 nautical miles due east to station B. Now the same headland bears due north (0°). How far is the headland from station B?



Two bearings from the ends of a known baseline fix the headland.

1. Draw A, then B 6 nautical miles east of A. Draw a line from B straight north.
2. From A draw a line at 45° , halfway between north and east. The two lines cross at the headland.
3. The triangle has a right angle at B (east and north are at right angles). The angle at A is 45° , so the angle at the headland is $180^\circ - 90^\circ - 45^\circ = 45^\circ$.
4. A triangle with two equal angles has two equal sides, so the side from B to the headland equals the side from A to B: 6 nautical miles.

Answer: The headland is 6 nautical miles due north of station B.

Example 2. Botany Bay is at about $34^{\circ}00'$ S. Possession Island is at about $10^{\circ}44'$ S. How far apart are they, measured straight north and south, in nautical miles? (One degree of latitude = 60 nautical miles, and one minute = 1 nautical mile.)

1. Both are south of the equator, so subtract: $34^{\circ}00' - 10^{\circ}44'$.
2. Borrow 1 degree as 60 minutes: $33^{\circ}60' - 10^{\circ}44' = 23^{\circ}16'$.
3. Change degrees to nautical miles: $23 \times 60 = 1,380$.
4. Add the minutes: $1,380 + 16 = 1,396$ nautical miles.

Answer: About 1,396 nautical miles north to south. The coast Cook actually followed was longer, about 2,000 miles, because it bends.

PRACTICE

1. **EASY** Which European first saw New Zealand, and in what year? What did Cook prove that this earlier sailor did not know?
2. **EASY** Name the two big mistakes on Cook's chart of New Zealand.
3. **MEDIUM** At its narrowest, Cook Strait is about 14 miles wide. On a chart where 1 inch stands for 7 miles, how wide is it on the paper?
4. **MEDIUM** Look at the map. In which direction did the *Endeavour* sail from Cape Farewell, at the northwest tip of the South Island, to Point Hicks in Australia?
(Use the map or drawing "Find Cape Farewell and Point Hicks." shown earlier in this lesson.)
5. **MEDIUM** A ship at station A sees an island due east (90°). The ship sails 4 nautical miles due north to station B. Now the island bears southeast (135°). How far is the island from station A?
6. **HARD** Cook charted about 2,400 miles of New Zealand's coast in about 180 days. About how many miles of coast did he chart each day, on average?
7. **HARD** The *Endeavour* struck the Great Barrier Reef on June 11, 1770. Cook claimed the east coast at Possession Island on August 22, 1770. How many days apart were these two events?
8. **CHALLENGE** Cook's orders said to claim land only with the consent of the people who lived there. At Possession Island he claimed the whole east coast of Australia without asking anyone. In two or three sentences, tell what Cook did well on this voyage and what he did wrong.

COMMON MISTAKES

- Using only one bearing. One line tells the direction to a headland but not how far away it is. You need two lines from two places to find where they cross.
- Measuring bearings from the wrong starting line. Bearings start at north (0°) and go clockwise, so east is 90° , not 270° .
- Thinking Cook discovered an empty land. New Zealand and Australia had been home to the Māori and to many Aboriginal peoples for a long time, and Dutch sailors had

already charted parts of both coasts.

Make it a game • Find the Headland. One player hides a small toy somewhere in the room. The other players stand at two marked spots and each points a yardstick at where the hider says “It is in that direction!” (the hider points to it from each spot). Lay the yardsticks on the floor along those directions. The first player to walk to where the lines cross and find the toy wins the round. Switch hiders and play five rounds.

Scripture. “The sea is his, and he made it: and his hands formed the dry land.” (Psalm 95:5, KJV)

Every bay, headland and reef that Cook drew had been shaped by God long before any chart. A good mapmaker draws what is really there, carefully and truthfully, so that others may travel safely.

Practice answers

1. Abel Tasman, in 1642. Cook sailed all the way around New Zealand and proved it was two main islands, not part of a great southern continent.
2. He drew Banks Peninsula as an island, and he drew Stewart Island as a peninsula joined to the South Island.
3. $14 \div 7 = 2$ inches.
4. West, a little north of west (from about $40^{\circ}30'$ S to about $37^{\circ}48'$ S).
5. 4 nautical miles. The triangle has a right angle at A, and the angle at B is 45° , so the two short sides are equal: the island is 4 nautical miles east of A.
6. $2,400 \div 180$ is about 13 miles a day (13.3).
7. June 11 to June 30 is 19 days, July has 31, and then 22 days of August: $19 + 31 + 22 = 72$ days.
8. Sample answer: Cook showed great skill and patience, charting thousands of miles of unknown coast so well that later sailors could trust his charts, and he saved his ship on the reef. But he claimed a land that was already home to many peoples without their consent, against his own orders, and his men shot at people at Poverty Bay and Botany Bay. Both things are true and should be told.

5.3 SCURVY AND THE SHIP'S DIET

OBJECTIVES

- Describe scurvy, the sailors' sickness, and explain that it comes from a lack of vitamin C found in fresh fruit and vegetables.
- Tell how James Lind's test of 1747 and James Cook's care for his crew helped defeat scurvy, and why that let ships stay at sea longer.
- Use speed, time and distance to judge whether a crew could cross an ocean before scurvy struck.

Warm-up. Look in your kitchen and make two piles (or two lists): foods that would still be good after six months in a wooden barrel on a ship with no refrigerator, and foods that would spoil in a week. Which pile has the fruit and fresh vegetables? Which pile would you rather eat for a whole year?

Video. Coming soon. Scurvy, James Lind's 1747 experiment and food on Captain Cook's ships (sauerkraut, portable soup, ship's biscuit): search Smithsonian, The History Guy, Royal Museums Greenwich (candidate, needs vetting), Homeschool Pop (Alternate).

KEY TERMS

scurvy

A sickness caused by going too long without vitamin C. Gums bleed and swell, teeth loosen, old wounds open, and the sufferer grows weak and can die.

vitamin C

A substance in fresh fruit and vegetables that the body needs every day but cannot make or store for long.

sauerkraut

Cabbage sliced fine and preserved in salt, where it slowly turns sour. It keeps for months in a barrel.

ration

The fixed amount of food or drink given to each person, such as a sailor's daily allowance of biscuit and meat.

fair test

An experiment where only one thing is changed and everything else is kept the same, so you can tell what made the difference.

CORE IDEAS

The story. In the days of sail, the most dangerous enemy of a long voyage was not storms or cannons. It was **scurvy**. After a month or two at sea on salt meat and hard biscuit, sailors' gums swelled and bled, their teeth came loose, old scars broke open and their legs grew

weak and spotted. From 1740 to 1744 a British squadron under George Anson sailed around the world. Of about 1,900 men who set out, more than 1,300 died, most of them from scurvy and other diseases, and only a handful in battle. Captains knew that fresh food seemed to help, but no one was sure what really worked.

How they figured it out. In 1747 a Scottish naval surgeon named James Lind did something new aboard HMS *Salisbury*. He took twelve sailors sick with scurvy, all as alike as he could find, and gave them the same food. Then he split them into six pairs and gave each pair a different remedy: cider, vinegar, sea water, a weak acid, a spicy paste, or two oranges and a lemon every day. That was a **fair test**, because only one thing changed. The two men who ate the oranges and lemons got better so quickly that one was fit for duty in about six days. Lind published his findings in 1753, but even he did not fully understand them, and the Navy was slow to act.

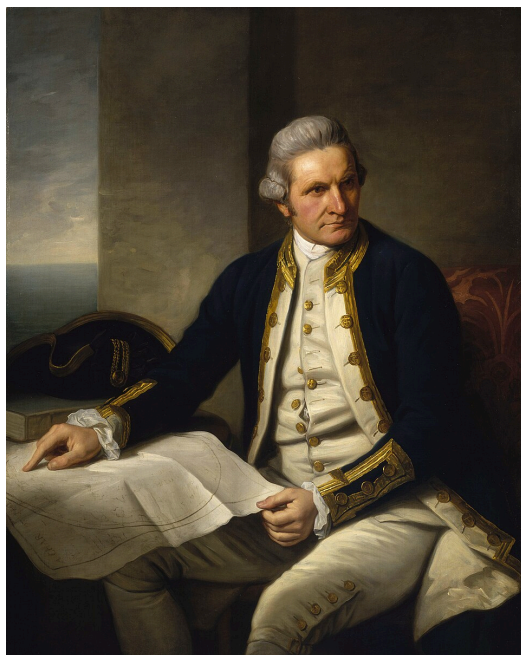
Cook's ship diet. When the *Endeavour* sailed in 1768, her hold was packed with salt beef and pork, ship's biscuit, dried peas, oatmeal, cheese and beer. Cook also carried new foods to test against scurvy: "portable soup" (dried meat broth in cakes), malt for a drink called wort, and 7,860 pounds of **sauerkraut**. At first the sailors refused the sour cabbage. So Cook had it served every day at the officers' table and let the men take it or leave it. He later wrote that once sailors saw their officers valued something, they wanted it too, and soon the sauerkraut had to be rationed. Cook could also be stern: at Madeira he had two men flogged for refusing their fresh beef.

Fresh food everywhere. Cook's greatest weapon was simple. At every landing he sent men to gather fresh food: fish, fruit, wild celery and the plant sailors called scurvy grass. In New Zealand on his second voyage he brewed beer from spruce leaves. He also kept his men clean and dry. Decks were scrubbed and aired, wet clothes were dried by small fires below decks, and he divided the crew into three watches instead of two so they got more sleep. On the second voyage, which lasted three years, he lost only one man to sickness, and none to scurvy. In 1776 the Royal Society gave him its Copley Medal for his paper on keeping sailors healthy.

The big idea. Today we know that scurvy comes from a lack of **vitamin C**, which the body cannot make for itself. Fresh fruit and greens are full of it. Raw sauerkraut has some, but boiling and long storage destroy much of it, and malt has almost none. Cook thought the malt helped most, but it was really the fresh food he gathered so faithfully. In 1795, the Royal Navy began giving lemon juice to all its sailors, and scurvy nearly vanished from the fleet.

Technology overcoming geography. The Pacific is the widest ocean on earth, with thousands of miles between some islands. A ship can only sail as far as her crew can stay alive. By understanding the ship's diet, sailors could stay healthy for months, and the great ocean was opened. God had already provided what they needed in the fruit and herbs of the earth; men had to learn to look for it.

PICTURE STUDY



Captain James Cook, Nathaniel Dance, 1776 (Cook sat for it on 25 May 1776) · Oil on canvas · National Maritime Museum, Greenwich, London

Nathaniel Dance painted this portrait of Captain Cook in London in 1776, after Cook returned from his second voyage and just before he left on his third. That same year the Royal Society honored him for keeping his crew free of scurvy.

Dance shows Cook in his captain's uniform, with his hand on one of his own charts. He does not hold a sword or stand on a battlefield. The painter chose to show Cook as a navigator and mapmaker.

Look closely

- Find Cook's hand. What is it resting on? Why might Cook have wanted to be painted with it?
- Look at his face. What words describe how he looks: proud, tired, serious, kind?
- Look at his clothes. What tells you he is an officer of the Royal Navy?
- Look at the colors. Which color stands out most?

Talk about it

1. If you were painted with one object that shows your work, what would it be?
2. Cook was famous for keeping his men healthy. How could a painter show that in a portrait?
3. Why do you think people in 1776 wanted a portrait of Cook?

Safety first. Iodine is poisonous if swallowed and stains skin and clothes. An adult should handle the iodine bottle and the hot water. Wear old clothes, work on newspaper, and do

not drink any of the test liquids.

PROJECT: WHICH FOODS FIGHT SCURVY? A VITAMIN C TEST

Like James Lind, you will run a fair test. You will use a blue starch and iodine mixture that loses its color when vitamin C is added. The fewer drops of a juice it takes to clear the blue, the more vitamin C the juice has.

You will need

- Tincture of iodine (2%, from a pharmacy), handled by an adult
- 1 teaspoon of cornstarch and a cup of hot water
- Six small clear cups and a measuring tablespoon
- An eyedropper or medicine dropper (rinse it between juices)
- Juices to test: fresh-squeezed orange juice, lemon juice, apple juice from a bottle, juice from raw (refrigerated) sauerkraut, orange juice that an adult has boiled for 10 minutes and cooled, and plain water
- Masking tape, a marker and your notebook

Steps

1. With an adult, stir 1 teaspoon of cornstarch into a little cold water, then stir it into a cup of hot water. Let it cool.
2. In a pitcher, mix about 2 cups of water, 1 tablespoon of the starch water, and about 10 drops of iodine. It should turn dark blue.
3. Label six cups with the names of the six juices. Pour 2 tablespoons of the blue liquid into each cup.
4. Before you test, write your prediction: which juice will clear the blue fastest? Which will not clear it at all?
5. Add the first juice one drop at a time, stirring after each drop. Count the drops until the blue color is gone. Stop at 40 drops if it never clears.
6. Rinse the dropper and test the next juice the same way. Keep everything the same except the juice.
7. Make a bar chart: one bar for each juice, showing the number of drops. Fewer drops means more vitamin C.
8. Write two sentences: Which food would you have wanted on Cook's ship? What did boiling do to the orange juice?

Tips

- The amounts of blue liquid must be the same in every cup, or the test is not fair.
- Dark juices like grape can hide the color change. Stick with light-colored juices.
- If the blue is so dark that nothing clears it, add more water to the pitcher and start again.

Check your work

- I kept my test fair by changing only one thing.
- I can read my bar chart and tell which juice had the most vitamin C.
- I can explain why boiled or old food helped sailors less than fresh food.

MAP NOTEBOOK

1. Draw a ship's barrel cut open to show what is inside: salt pork, biscuit, peas and sauerkraut. Label each food and circle the one that fights scurvy.
2. Draw Lind's six pairs of sailors in a row, each with its remedy. Put a star by the pair that got well.
3. Make a "fresh food map": sketch the outline of the Pacific and mark three places where Cook stopped for fresh food (Tahiti, New Zealand, Hawaii) with a fruit or plant drawing at each.

From history. In 1795 the Royal Navy began giving lemon juice to all its sailors, largely through the efforts of a physician named Gilbert Blane. Later the Navy switched to lime juice from British colonies in the West Indies, which is why British sailors were nicknamed "limeys." Limes, it turned out, have less vitamin C than lemons, and scurvy came back on some long polar voyages in the 1800s. Scientists did not finally identify vitamin C until the early 1930s.

WORKED EXAMPLES

Example 1. A ship averages 4 knots (4 nautical miles every hour), day and night. She must sail 3,000 nautical miles between two islands. Scurvy usually begins to show after about six weeks without fresh food. Is the crew likely to reach land before scurvy strikes?

1. Distance in one day: $4 \text{ nautical miles per hour} \times 24 \text{ hours} = 96 \text{ nautical miles a day}$.
2. Days needed: $3,000 \div 96$ is about 31.25, so about 32 days.
3. Six weeks is $6 \times 7 = 42$ days.
4. 32 days is less than 42 days, so they should arrive first, but only by about 10 days. A storm or calm could use that up.

Answer: Yes, probably: about 32 days, which is under six weeks, but with only about 10 days to spare.

Example 2. The *Endeavour* carried 7,860 pounds of sauerkraut for about 94 people. About how many pounds was that for each person? If the voyage was planned to last two years (about 104 weeks), about how much was that for each person each week?

1. Pounds for each person: $7,860 \div 94$ is about 83.6, so about 84 pounds.
2. Weeks in two years: about 104.
3. Pounds each week: $84 \div 104$ is about 0.8 pound.
4. That is a little less than 1 pound a week, about the size of a small bowl every few days.

Answer: About 84 pounds per person, or a little less than 1 pound (about 0.8 pound) per person each week.

PRACTICE

1. **EASY** What causes scurvy? Name three signs that a sailor has it.
2. **EASY** In Lind's test of 1747, how many sailors were there, and how many of them were given oranges and lemons? What happened to them?
3. **EASY** Name three things Cook did, besides serving sauerkraut, to keep his crew healthy.
4. **MEDIUM** A ship sails at 5 knots for 24 hours a day. How many days will it take to sail 4,800 nautical miles? Is that more or less than six weeks?
5. **MEDIUM** Cook stopped at Madeira, at about 33° N, for fresh food after leaving Plymouth, at about 50° N. How many degrees of latitude did he sail south? How many nautical miles is that, north to south?
6. **HARD** Suppose each of 94 sailors ate 2 pounds of sauerkraut a week. How many weeks would 7,860 pounds last?
7. **HARD** Cook believed malt was the best cure for scurvy. Was he right? What really kept his men well?
8. **CHALLENGE** Cook's sailors would not eat sauerkraut until he served it at the officers' table. In two or three sentences, explain why this worked and what it teaches about leading people.

COMMON MISTAKES

- Thinking scurvy is caught from other people like a cold. It is not catching; it comes from missing vitamin C in the diet.
- Thinking sauerkraut alone saved Cook's men. Fresh food gathered on land did most of the work; cooked or long-stored food loses much of its vitamin C.
- Forgetting to turn knots into miles per day. Multiply the knots by 24 hours before dividing the distance.

Make it a game · Pack the Ship's Hold. Make cards for twenty foods, some that keep (salt pork, biscuit, dried peas, sauerkraut, cheese) and some that are fresh (oranges,

lemons, celery, fish, coconuts). Players take turns drawing a card and saying whether it goes in the hold for a long voyage or must be gathered fresh at the next island, and whether it fights scurvy. Each right answer scores a point. Bonus point for naming a place in the Pacific where Cook could have found it.

Scripture. “And God said, Behold, I have given you every herb bearing seed, which is upon the face of all the earth, and every tree, in the which is the fruit of a tree yielding seed; to you it shall be for meat.” (Genesis 1:29, KJV)

God provided food for man in the plants and fruits of the earth. Lind and Cook did not invent the cure for scurvy; they discovered, by careful testing, the good gift God had already given.

Practice answers

1. Going too long without vitamin C, which comes from fresh fruit and vegetables. Signs: swollen, bleeding gums; loose teeth; old wounds opening; weakness; spots on the legs (any three).
2. Twelve sailors in six pairs; two were given oranges and lemons. They got better faster than all the others; one was fit for duty in about six days.
3. Any three: gathered fresh food (fruit, fish, wild celery, scurvy grass) at every landing; brewed spruce beer; kept the ship clean and aired; dried clothes and decks with small fires; gave the men more sleep with three watches.
4. $5 \times 24 = 120$ nautical miles a day. $4,800 \div 120 = 40$ days. That is just under six weeks (42 days).
5. $50 - 33 = 17$ degrees. $17 \times 60 = 1,020$ nautical miles.
6. $94 \times 2 = 188$ pounds a week. $7,860 \div 188$ is about 41.8, so about 41 full weeks (almost 42).
7. No. Malt has almost no vitamin C. What really worked was the fresh fruit, greens and other fresh food he gathered at every landing, with a little help from raw sauerkraut. His care for cleanliness and rest kept the men stronger too.
8. Sample answer: The sailors trusted what their officers chose for themselves more than what they were simply ordered to eat. When the men saw the officers eating it gladly, they wanted it too. A good leader often leads best by example, doing first what he asks others to do.

5.4 COOK'S DEATH IN HAWAII

OBJECTIVES

- Trace Cook's third voyage (1776–1780) on a map: to Hawaii, up the northwest coast of America, through the Bering Strait to the Arctic ice, and back to Hawaii.
- Tell the story of Cook's death at Kealakekua Bay on February 14, 1779, fairly, from the side of the British and the side of the Hawaiians.
- Judge Cook honestly, naming both his great skill and courage and the real wrongs done on his voyages.

Warm-up. Imagine a huge ship with tall masts and strange-looking men sails into your town's harbor. You have never seen anything like it. Write down three questions you would want answered about the strangers. Now imagine you are a sailor on that ship, landing on an island no one from your country has ever seen. Write three questions you would ask about the islanders. How are your two lists alike?

Watch. *18th January 1778: Captain James Cook becomes the first known European to visit the Hawaiian Islands* (HistoryPod, 2:43). https://www.youtube.com/watch?v=PZI5xJe7_KE

After the story: watch to see Cook's first arrival in the Hawaiian Islands at Kaua'i in January 1778, a year before the events at Kealakekua Bay.

Note: Captions were not available to check; preview it first. The description says the first meetings were peaceful; the video may not cover Cook's death. The video covers the first visit in January 1778, not Cook's death at Kealakekua Bay in February 1779. It also uses the name 'Sandwich Islands.'

KEY TERMS

Northwest Passage

A hoped-for sea route around the top of North America, linking the Atlantic and Pacific Oceans. Cook searched for its Pacific end.

Makahiki

The Hawaiian season of harvest and peace, held in honor of the god Lono, when war was set aside and gifts were brought to the chiefs.

chief

A ruler or leader of a people. Kalani'ōpu'u was the ruling chief of the island of Hawaii when Cook arrived.

hostage

A person held by one side until the other side does what is demanded, such as returning a stolen boat.

misunderstanding

When two people or peoples take each other's words or actions to mean something they do not mean.

CORE IDEAS

The story. In July 1776 Captain Cook sailed from Plymouth on his third great voyage, in the *Resolution*, with Charles Clerke commanding the *Discovery*. He had two tasks. He was to carry home Mai, a young man from the island of Raiatea who had visited England, and then to search the North Pacific for the western end of a **Northwest Passage** around the top of America. Cook was now nearly fifty and worn by years at sea. On this voyage he was often short-tempered. On the island of Moorea in 1777, when a goat was stolen, he had houses and canoes burned until it was returned. Even some of his own officers thought he had gone too far.

Hawaii. In January 1778, sailing north from Tahiti, the ships came upon islands no European had recorded. On January 20 Cook landed at Waimea on Kauai. He named the group the Sandwich Islands after the Earl of Sandwich, head of the Navy. The Hawaiians had lived there for many centuries, descendants of Polynesian canoe voyagers. Cook was amazed to find that they spoke a language much like that of Tahiti, thousands of miles away, and he wondered at how one people had spread so far across the ocean. Cook tried to keep sick sailors from going ashore, but his men still brought disease to the islands, which later killed many Hawaiians.

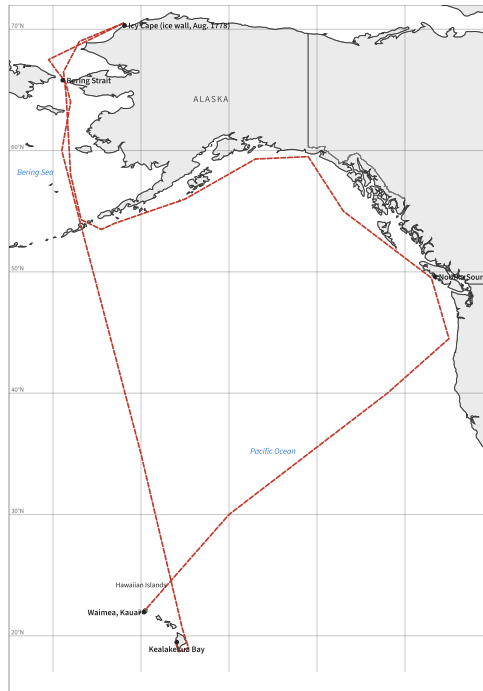
The far north. From Hawaii Cook sailed northeast to the coast of what is now Oregon, then north to Nootka Sound, where his men traded for sea otter furs. He charted the coast of Alaska, passed through the Bering Strait between America and Asia, and pushed into the Arctic Ocean. In August 1778, near 70° N, a solid wall of ice stretched across the sea. There was no way through. Cook turned south to spend the winter in Hawaii and try again the next summer.

Kealakekua Bay. On January 17, 1779, the ships anchored in Kealakekua Bay on the island of Hawaii. Hundreds of canoes and thousands of people came out to greet them. It was the season of **Makahiki**, the festival of the god Lono, and Cook was led to a temple and honored with ceremonies. Historians still argue about whether the Hawaiians thought Cook was Lono himself or honored him as a great chief. The ruling chief, Kalani'ōpu'u, gave the ships pigs, fruit and gifts, but feeding two ships for weeks was a heavy burden. On February 4 the ships left. A storm broke the *Resolution's* foremast, and on February 11 they came back to mend it. This time the welcome was cold. There were quarrels and thefts, and on the night of February 13 someone took the *Discovery's* large boat, the cutter.

February 14, 1779. In the morning Cook went ashore with a few marines to bring Kalani'ōpu'u aboard and hold him as a **hostage** until the boat came back, as he had done on other islands. The old chief began to walk with him, but his wife and other chiefs begged him not to go. Then news came that a Hawaiian chief had been shot dead by a British boat across the bay. Angry, armed men pressed in. Cook fired his gun; stones flew; the marines fired; and at the water's edge Cook was struck down and killed, along with four marines. A number of

Hawaiians, including several chiefs, died too. The Hawaiians treated Cook's body as they treated the body of a high chief, and later returned some of his remains, which were buried at sea. In the days that followed, angry British sailors burned a village and killed more Hawaiians. Captain Clerke died of illness that summer, and the ships reached England in October 1780.

The big idea. Cook's death was a sad meeting of two peoples who did not understand each other. Each side had its own laws, its own honor and its own fears. Cook was one of the greatest navigators and mapmakers who ever lived, and he cared for his men's lives, yet he also used force when he grew impatient. We tell both truths. Scripture says God "hath made of one blood all nations of men," the sailors from England and the people of Hawaii alike.



Cook's third voyage in the North Pacific, 1778-1779.

PICTURE STUDY



The Death of Captain Cook, Francesco Bartolozzi and William Byrne, engraved after a painting by John Webber, 1784 · Engraving on paper · Copies in many collections, including the National Maritime Museum, Greenwich, and the National Library of Australia, Canberra

John Webber was the official artist on Cook's third voyage. He was aboard ship, not on the shore, when Cook was killed, but after the voyage he painted the scene from what the survivors told him. Two London engravers, Francesco Bartolozzi and William Byrne, turned his picture into this print in 1784, and copies were sold all over Europe.

Pictures like this one helped make Cook a hero in the eyes of Europe. As you study it, remember that it was made in London, years after the event, by people who wanted to honor Cook. A Hawaiian picture of the same day would look very different.

Look closely

- Find Captain Cook. What is he doing with his arm? What do you think the artist wanted you to believe about him?
- Find the Hawaiian warriors. What weapons do they carry? How does the artist show them?
- Look at the boats in the water and the marines. Who is firing and who is fleeing?
- Look at the land behind. What clues tell you this is a tropical island?

Talk about it

1. The eyewitnesses did not all agree about what Cook was doing when he fell. Why would an artist choose one version?
2. How might Kalani'ōpu'u's people have told the story of this day?

3. Is a picture made years later a good source of history? What else should we read to know what happened?

PROJECT: MAP OF COOK'S THREE VOYAGES

You will draw a large map of the Pacific and trace all three of Cook's voyages in three colors, with the key places and dates. Beside it, you will write the story of February 14, 1779, twice: once as a British sailor and once as a Hawaiian.

You will need

- A large sheet of paper (poster board or two pieces taped together)
- An atlas, globe or printed outline map of the Pacific to copy
- Three colored pencils or markers (one for each voyage)
- Pencil, ruler and eraser
- Lined paper for the two stories

Steps

1. Lightly draw the Pacific Ocean with the coasts around it: the Americas on the right, Asia and Australia on the left, Antarctica at the bottom. Put the Pacific in the middle, so 180° longitude runs down the center of your map.
2. Draw lines for the equator, the Tropic of Cancer, the Tropic of Capricorn and the Antarctic Circle, and label them.
3. First voyage (1768–1771), color 1: Plymouth, Cape Horn, Tahiti, around New Zealand, up the east coast of Australia, Batavia, around Africa, home.
4. Second voyage (1772–1775), color 2: Plymouth, Cape Town, far south across the Antarctic Circle, New Zealand, the wide loops through the Pacific to Tahiti, Tonga and Easter Island, around Cape Horn, home.
5. Third voyage (1776–1780), color 3: Plymouth, Cape Town, Tasmania, New Zealand, Tahiti, Hawaii, Nootka Sound, Alaska, the Bering Strait, the ice near 70° N, back to Hawaii.
6. Mark these places with a dot and a date: Point Venus (1769), Cook Strait (1770), Botany Bay (1770), Antarctic Circle (1773), Waimea, Kauai (1778), Icy Cape (1778), Kealahou Bay (1779).
7. Add a key showing the three colors, a compass rose and a title.
8. On lined paper, write two short accounts of February 14, 1779: one by a British marine and one by a Hawaiian who was on the shore. Use only the facts from the lesson, but let each speaker tell what he saw and feared.

Tips

- Use your atlas grid: put each place by its latitude and longitude, not just by guessing.
- Draw the voyage lines lightly in pencil first. They cross each other in many places.
- In your two accounts, be fair to both sides. Neither speaker knew everything that was happening.

Check your work

- My map shows all three voyages in three colors with a key.
- I placed at least seven places with their dates.
- My two accounts tell the same events truthfully from two points of view.

MAP NOTEBOOK

1. Sketch the Hawaiian Islands and label Kauai, Maui, Hawaii and Kealakekua Bay. Write the dates January 20, 1778, and February 14, 1779.
2. Draw the ice wall Cook met in the Arctic in August 1778, with the ships in front of it. Label the latitude, about 70° N.
3. Make a two-column chart titled "Captain Cook, Judged Honestly": Courage and skill on one side, Wrongs done on the other. Write at least three things in each column from this whole unit.

From history. On the shore of Kealakekua Bay, near the spot where Cook fell, stands a white stone monument raised in 1874. It can be reached only by boat, kayak or a long hike. Nearby are the stone walls of the old Hawaiian village of Ka'awaloa, where Kalani'ōpu'u lived.

WORKED EXAMPLES

Example 1. Kealakekua Bay is at about $19^{\circ}30'$ N. Cook's farthest point north, at the Arctic ice, was about $70^{\circ}44'$ N. How far apart are they, measured straight north and south, in nautical miles?

(Use the map or drawing "Find Kealakekua Bay and Icy Cape." shown earlier in this lesson.)

1. Both are north of the equator, so subtract: $70^{\circ}44' - 19^{\circ}30' = 51^{\circ}14'$.
2. Change the degrees: $51 \times 60 = 3,060$ nautical miles.
3. Add the minutes: $3,060 + 14 = 3,074$ nautical miles.

Answer: About 3,074 nautical miles, north to south. The real route was much longer, because it bent along the coast of America.

Example 2. Cook's ships anchored in Kealakekua Bay on January 17, 1779. They left on February 4, came back on February 11, and Cook was killed on February 14. How many days after first arriving did Cook die? How many days were the ships away?

1. From January 17 to January 31: $31 - 17 = 14$ days.
2. Add the 14 days of February: $14 + 14 = 28$ days.
3. Days away: from February 4 to February 11 is $11 - 4 = 7$ days.

Answer: Cook died 28 days (four weeks) after first arriving. The ships were away for 7 days.

PRACTICE

1. **EASY** What name did Cook give the Hawaiian Islands, and whom were they named after?
2. **EASY** Name the two main tasks of Cook's third voyage.
3. **MEDIUM** Look at the map. In which direction did Cook sail from Kauai to Nootka Sound? What stopped him in the Arctic in August 1778?
(Use the map or drawing "Follow the route north from Kauai." shown earlier in this lesson.)
4. **MEDIUM** Kauai is at about 22° N. Nootka Sound is at about 50° N. How many nautical miles apart are they, north to south?
5. **MEDIUM** Kealakekua Bay is at about 156° W. How many hours and minutes is local time there behind Greenwich time? ($15^\circ = 1$ hour, and $1^\circ = 4$ minutes.)
6. **HARD** The third voyage left Plymouth in July 1776 and the ships returned to England in October 1780. About how long was the voyage? Who was in command at the end?
7. **HARD** Put these in order: (a) the *Discovery's* cutter is stolen; (b) Cook lands at Waimea, Kauai; (c) the ships turn back from the Arctic ice; (d) the foremast breaks and the ships return to Kealakekua Bay; (e) Cook is killed; (f) the ships arrive at Kealakekua Bay during Makahiki.
8. **CHALLENGE** In a short paragraph, explain why Cook's death can be called "a sad meeting of two peoples." Include one thing the British did wrong and one reason the Hawaiians were angry.

COMMON MISTAKES

- Telling the story as if the Hawaiians attacked for no reason. Cook was trying to take their ruling chief hostage, and a chief had just been killed by the British.
- Telling the story as if Cook were simply a villain. He was a great navigator who saved many lives through care for his crew; his death came out of a misunderstanding and his own impatience that day.
- Mixing up the islands. Cook first landed on Kauai in 1778, but he died on the island of Hawaii (the Big Island) in 1779.

Make it a game · Two Sides of the Bay. Split into two teams, the “Ships” and the “Shore.” A leader reads one event from Cook’s third voyage, such as “The ships return with a broken mast.” Each team has thirty seconds to say what their side might have thought or feared about it. Score a point for any answer that fits the facts. Then switch sides and play again, so everyone has to see both points of view.

Scripture. “And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;” (Acts 17:26, KJV)

The sailors of England and the people of Hawaii were of one blood, made by the same God. When peoples meet for the first time, both sides need patience, honesty and humility, because misunderstanding can lead quickly to tragedy.

Practice answers

1. The Sandwich Islands, after the Earl of Sandwich, the head of the British Navy (First Lord of the Admiralty).
2. To carry Mai home to the islands near Tahiti, and to search the North Pacific for the western end of a Northwest Passage around the top of North America.
3. Northeast. A solid wall of ice across the sea near Icy Cape, about 70° N.
4. $50 - 22 = 28$ degrees. $28 \times 60 = 1,680$ nautical miles.
5. $156 \div 15 = 10$ with 6 degrees left over. $6 \times 4 = 24$ minutes. So about 10 hours 24 minutes behind Greenwich.
6. About 4 years and 3 months. Neither Cook nor Clerke: Clerke died of illness in August 1779, and John Gore brought the ships home.
7. (b) January 1778, (c) August 1778, (f) January 17, 1779, (d) February 1779, (a) night of February 13, 1779, (e) February 14, 1779.
8. Sample answer: The British and the Hawaiians did not understand each other’s customs, and both sides were afraid. Cook tried to take the ruling chief as a hostage to get a stolen boat back, which to the Hawaiians was an insult to their king, and a British boat had just shot a chief across the bay. The Hawaiians had already fed the ships for weeks and were tired of the strangers. Fighting broke out, and men on both sides died who need not have died.

UNIT 5 REVIEW

Answer each question. Show your work for calculations and use complete sentences for explanations. Use 60 nautical miles for each degree of latitude and 15 degrees of longitude for each hour of time. The review is worth 50 points.

1. (4 pts) Why did the Royal Society send Cook to Tahiti, and on what date did the event happen?
2. (4 pts) Tahiti is at about 150° W. When it is noon at Greenwich, what time is it at Tahiti? Show how you know.
3. (4 pts) What is parallax? Give an example you can see with your own eyes.
4. (5 pts) A ship at station A sees a cape bearing northeast (45°). She sails 5 nautical miles due east to station B, where the cape bears due north (0°). Draw a sketch and find how far the cape is from B.
5. (4 pts) What did Cook prove by sailing around New Zealand, and what two mistakes did his chart contain?
6. (4 pts) Point Hicks is at about 38° S and the tip of Cape York is at about 11° S. How far apart are they north to south, in nautical miles?
7. (5 pts) What causes scurvy? Name three things Cook did to keep his sailors from getting it.
8. (4 pts) A ship averages 4 knots, day and night. How many days will she need to sail 2,400 nautical miles? Will she arrive before six weeks without fresh food are up?
9. (4 pts) What did James Lind do in 1747 that made his test a fair test?
10. (4 pts) On a map, Cook sailed from Kauai (about 22° N) north to the Arctic ice (about 70° N). What was he searching for, and how many degrees of latitude did he cross?
11. (4 pts) Tell in four or five sentences what happened at Kealakekua Bay from January 17 to February 14, 1779.
12. (4 pts) Judge Cook honestly: name one example of his courage or skill and one real wrong done on his voyages.

UNIT PROJECT: COOK'S PACIFIC: THREE VOYAGES AND A CHART OF MY OWN

Make a large map of the Pacific showing all three of Cook's voyages in three colors, with at least seven places and dates (Point Venus, Cook Strait, Botany Bay, the Antarctic Circle, Kauai, Icy Cape, Kealakekua Bay). Beside it, include the coastline you charted by triangulation from your toy boat, with your bearing table, and your vitamin C bar chart. Finish with a paragraph titled "Captain Cook, Judged Honestly," naming his courage and skill and the real wrongs of his voyages, and two short accounts of February 14, 1779, one by a British marine and one by a Hawaiian on the shore.

- **Accuracy:** Routes, places and dates are correct and placed by latitude and longitude; the triangulated chart closely matches the real floor coast.
- **Records:** The bearing table and vitamin C chart are complete, labeled and neatly recorded.

- **Honest judgment:** The paragraph and the two accounts are fair and truthful, naming both Cook's achievements and real wrongs without exaggeration.
- **Care:** The map has a key, compass rose, scale and title, and the whole portfolio is neat and easy to read.

Answer key

1. To watch and time the transit of Venus (Venus crossing the face of the sun), on June 3, 1769. Timings from places far apart helped astronomers work out the distance from the earth to the sun.
2. $150 \div 15 = 10$ hours. Tahiti is west of Greenwich, so it is 10 hours behind: noon – 10 hours = 2:00 a.m.
3. Parallax is the way a near object seems to shift against a far background when seen from two different places. Example: hold up your thumb and look with one eye, then the other; the thumb seems to jump.
4. 5 nautical miles due north of B. The triangle has a right angle at B and 45° at A, so the angle at the cape is also 45° , and the two short sides are equal.
5. He proved New Zealand was two main islands with a strait between them (Cook Strait), not part of a southern continent. Mistakes: Banks Peninsula drawn as an island, and Stewart Island drawn as a peninsula.
6. $38 - 11 = 27$ degrees. $27 \times 60 = 1,620$ nautical miles.
7. A lack of vitamin C, found in fresh fruit and vegetables. Any three: fresh food gathered at every landing; sauerkraut served at the officers' table so the men would eat it; spruce beer; clean, aired, dry decks; more rest with three watches.
8. $4 \times 24 = 96$ nautical miles a day. $2,400 \div 96 = 25$ days. Yes: 25 days is less than 42 days.
9. He chose twelve sailors with scurvy who were as alike as possible, gave them all the same food, and changed only one thing, the remedy, for each pair. The pair given oranges and lemons recovered fastest.
10. He was searching for the Pacific end of a Northwest Passage around the top of North America. $70 - 22 = 48$ degrees (about 2,880 nautical miles north to south).
11. The ships arrived on January 17 during the Makahiki season and were greeted with great ceremony and gifts. They left on February 4, but a storm broke the Resolution's foremast and they returned on February 11 to a colder welcome. On the night of February 13 the Discovery's cutter was stolen. On February 14 Cook went ashore to take the chief Kalani'ōpu'u hostage until the boat was returned; when news came that a chief had been killed by the British, fighting broke out and Cook, four marines and a number of Hawaiians were killed.
12. Sample: Skill: he charted New Zealand and eastern Australia so well that sailors used his charts for many years (or: he kept his crews free of scurvy). Wrong: he claimed eastern Australia without the consent of its peoples (or: his men shot Māori at Poverty Bay; he burned houses and canoes on Moorea; he tried to take a Hawaiian chief hostage).

MISSIONARIES AS GEOGRAPHERS

Jesus told His disciples, “Go ye into all the world, and preach the gospel to every creature” (Mark 16:15). To go into all the world, you have to know where the world is. In this unit you will meet four Christians from Britain who took that command so seriously that they became geographers: they studied maps, measured latitudes, followed rivers into lands Europeans barely knew, and sent home letters, journals and maps that filled in the blank spaces. Our series verse reminds us why they went: “And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;” (Acts 17:26).

You will sail with William Carey, a shoemaker with a homemade wall map, around the Cape of Good Hope to India in 1793. You will walk with David Livingstone and his Makololo companions from the Atlantic to the Indian Ocean and stand with him at the edge of Victoria Falls in 1855. You will go up the Yangtze River with Hudson Taylor’s China Inland Mission, and paddle the creeks of the Cross River with Mary Slessor, a Dundee mill girl who became “Ma” to the peoples of Calabar.

We will tell their stories honestly. These missionaries showed great courage and skill, and they fought real evils: the burning of widows in India, the slave trade in Africa, the opium trade in China and the killing of twin babies in Calabar. But they also made mistakes, their families often paid a heavy price, and they depended on guides, boatmen, translators and friends whose names are mostly forgotten. Along the way you will practice the map skills of this course: latitude and longitude, distances by degrees, routes by sea and river, and the climates that shaped every journey.

BEFORE YOU BEGIN

- Can read latitude and longitude in whole degrees and tell north from south and east from west (Unit 2 and Unit 3)
- Knows that one degree of latitude is about 69 miles (111 km)
- Can count the days between two dates using the lengths of the months
- Can find the continents, oceans, the equator and the Cape of Good Hope on a world map (Unit 1)

MASTERY CHECKLIST

- I can tell the stories of William Carey, David Livingstone, Hudson Taylor and Mary Slessor and say where and when each one went.
- I can trace the sea route from Britain around the Cape of Good Hope to India and China, and Livingstone’s route across Africa, on a map.
- I can find the north-south distance between two places using degrees of latitude, and the number of days of a voyage from its dates.

- I can explain how climate (latitude, heat and rain) and rivers shaped each missionary's journeys.
- I can judge these missionaries honestly, naming their courage and good works as well as their failures and the wrongs of their times, such as the slave trade and the opium trade.

OPTIONAL BOOKS AND RESOURCES

- **Livingstone Online** (<https://livingstoneonline.org/>): Free. A digital library of David Livingstone's own manuscripts, letters, maps and field diaries, with pictures of the original pages. Best for a parent to browse first and choose a page or map to show (Lesson 6.2).
- **David Livingstone, *Missionary Travels and Researches in South Africa* (free at Project Gutenberg)** (<https://www.gutenberg.org/ebooks/search/?query=Livingstone+Missionary+Travels>): Free. Livingstone's own 1857 account of his crossing of Africa. The book is long and written for adults; a parent can read aloud the short passage in which he first sees Victoria Falls (Lesson 6.2).

6.1 WILLIAM CAREY GOES TO INDIA ★

OBJECTIVES

- Tell how William Carey, a village shoemaker, studied the map of the world and sailed to India in 1793.
- Trace the sailing route from England around the Cape of Good Hope to Calcutta and find its places by latitude and longitude.
- Explain how Carey used geography (countries, peoples, languages and distances) to plan his mission, and name both his achievements and his hardships honestly.

Warm-up. Tape a sheet of paper to the wall at your eye level. Look at a globe or world map and list five countries on the paper. Beside each one, write one thing you know about the people who live there: a language, a food or a faith. How many could you fill in? William Carey did this same thing on the wall of his shoemaker's shop, for the whole world.

Watch. *The Continuing Growth of Christianity in India - "Ends of the Earth"* (Drive Thru History with Dave Stotts, 4:01). https://www.youtube.com/watch?v=7V_58L6PSkE

As review: watch Dave Stotts show how Christianity has kept growing in India, and think about how William Carey's work at Serampore helped begin that growth.

Note: Captions were not available to check; preview it first. It is a clip from a TBN series on Christian history, and it may only mention Carey briefly. The title points to the church in India in general. It may not cover Carey's 1793 voyage or his Bible translations in detail.

KEY TERMS

missionary

A person sent to another place, often far away, to tell people about Jesus Christ and to serve them.

survey

A careful look at a whole subject, such as a list of all the countries of the world with their sizes, peoples and faiths.

translation

Putting words from one language into another, such as putting the Bible into Bengali.

monsoon

A wind that changes direction with the seasons, bringing a long rainy season to India.

Cape of Good Hope

The rocky point near the southern tip of Africa that sailing ships went around on the way from Europe to India.

CORE IDEAS

The story. In the 1780s, in the English Midlands, a young shoemaker named William Carey sat at his bench with a leather shoe in his lap and a map on the wall in front of him. He had made the map himself out of sheets of paper pasted together, and on it he wrote what he learned about each country: how many people lived there and what they believed. He read everything he could find, especially the published voyages of Captain Cook, and he taught himself Latin, Greek, Hebrew, Dutch and French. Carey was poor, he had little schooling, and he became the pastor of a small Baptist church. But the more he looked at his map, the more he asked one question: why were Christians not taking the gospel to the rest of the world?

How he figured it out. In 1792 Carey published a small book with a very long title. People call it simply the *Enquiry*. In it he did something no one had quite done before: he made a **survey** of the whole world in tables. Country by country, he listed its length and breadth in miles, its number of people and its religion. It was a geography book with a purpose. On May 31, 1792, at Nottingham, he preached on Isaiah 54:2, “Enlarge the place of thy tent.” His hearers remembered his two points as: **Expect great things from God; attempt great things for God.** That October, in a house in Kettering, a small group of pastors started the Baptist Missionary Society, and Carey offered to go.

The voyage. The British East India Company, which ruled much of Bengal, did not want missionaries in its lands, so Carey and his family could not get passage on an English ship. Instead they sailed on a Danish ship on June 13, 1793. The ship went south through the Atlantic, around the **Cape of Good Hope** at the tip of Africa, and across the Indian Ocean. They landed at Calcutta (today Kolkata) on November 11, 1793, about five months later. Carey was thirty-one. He never saw England again.

Hard years, told honestly. The first years in Bengal were bitter. Carey’s wife Dorothy had not wanted to leave England. Money ran out, the family moved into the swampy countryside, and their five-year-old son Peter died of fever. Dorothy’s mind broke under the grief, and she suffered from serious mental illness for the rest of her life. Carey worked as manager of an indigo factory to feed his family. In 1800 he moved to Serampore, a Danish town on the Hooghly River a few miles above Calcutta, where he joined Joshua Marshman and William Ward. With Indian scholars working beside them, they printed the Bible, in whole or in part, in more than thirty languages of India and Asia. Carey also spoke out for years against *sati*, the burning of widows on their husbands’ funeral fires; the government of Bengal banned it in 1829, and Carey translated the new law into Bengali.

On the map. Look at the map of Carey’s voyage. London is at about 52°N. The Cape of Good Hope is at about 34°S. Calcutta is at about 23°N, 88°E. A ship could not sail in a straight line from England to India, because Africa is in the way. It had to go far south, cross the equator twice, and use the trade winds and the seasonal **monsoon** winds of the Indian Ocean. Geography decided the route, and the route decided that the trip took months, not weeks.

The big idea. Carey believed that maps are not only for traders and navies. A Christian who studies the world learns where people live, what languages they speak and how to reach them. Carey stayed in India for forty-one years as a missionary, translator, teacher and botanist, and the society he helped start sent out many others. His map on the shop wall had become a plan for his life.



The sailing route of William Carey's voyage, June 13 to November 11, 1793 (the line shows the usual sea route, not the ship's exact track).

PICTURE STUDY



A Map of Hindoostan, James Rennell, Surveyor General of Bengal, 1782 (with later editions) · Engraved map on paper, printed in London · Copies are held in major map libraries, including the British Library, London, and the Library of Congress, Washington, D.C.

James Rennell was a young British naval officer who became the Surveyor General of Bengal. For years he and his survey parties measured the rivers and roads of Bengal, and in 1782 he published the best map of India that Europeans had yet seen. It was the kind of map William Carey would have studied before he sailed, and it showed the great rivers, the Ganges and the Hooghly, along which Carey would live and work.

Rennell is sometimes called the father of Indian geography. His map was built from careful measurements of distances and directions, checked by observations of latitude, the same skills you learned in Unit 2.

Look closely

- Find the Ganges River and follow it down to the sea. Where does it split into many mouths?
- Find Calcutta near the mouths of the Ganges. Is it on the open coast or up a river?
- Look at the mountains along the top of the map. What great range is that?
- Find the decorated title panel. What pictures did the engraver put there?

Talk about it

1. What parts of this map look well known, and what parts look empty or uncertain? Why might that be?
2. Why would a missionary who wanted to translate the Bible need to know where the rivers and provinces were?

3. How is this map different from the paper map Carey pasted together in his shop?

PROJECT: A MISSIONARY JOURNEY MAP, PART 1: CAREY'S VOYAGE AND A LETTER HOME

This is the first part of the unit project. You will start a large journey map, mark William Carey's voyage from England to India, and write a letter home as if you were on board the ship. In each lesson of this unit you will add another journey and another letter.

You will need

- A large sheet of paper (poster board, or four sheets of paper taped together)
- A printed outline map of the world, or a globe to copy from
- Pencil, eraser, colored pencils and a fine black pen
- A red pencil or marker for routes
- Lined paper, and a tea bag (optional, for making the letter look old)

Steps

1. Draw (or trace) the outline of the world on your large sheet, with the continents and oceans. Leave room at the edges for letters and pictures.
2. Draw the equator and label it 0°. Add lines for 30°N and 30°S if you can.
3. Mark London (about 52°N, 0°), the Cape of Good Hope (about 34°S, 18°E) and Calcutta (about 23°N, 88°E) with dots and labels.
4. In red, draw Carey's route: south through the Atlantic, around the Cape of Good Hope, and northeast across the Indian Ocean to Calcutta. Add small arrows to show the direction.
5. Write the dates on the route: "Sailed June 13, 1793" near England and "Landed November 11, 1793" near Calcutta.
6. Write a letter home of about eight sentences, dated at sea in 1793, as if you were one of the Carey children. Tell about crossing the equator, the long days at sea, rounding the Cape, and what you hope to see in India.
7. If you like, rub the letter lightly with a damp tea bag and let it dry so that it looks old. Keep it in a folder with your map.

Tips

- Use light pencil first. You will add three more journeys in the next lessons, so leave Africa, China and West Africa clear.
- A sailing ship's route is curved, not straight, because it follows the winds. Your route should swing far out into the Atlantic.

Check your work

- My map shows the equator and the three places marked in the right hemispheres.
- My red route goes around the Cape of Good Hope with arrows and dates.

- My letter gives real details of the voyage and is written in the voice of someone on board.

MAP NOTEBOOK

1. Draw Carey's shoemaker's bench with his paper map on the wall behind it. On the map, write the names of three countries and one fact about each.
2. Copy Carey's two points in your best handwriting: "Expect great things from God; attempt great things for God." Underline the two verbs.
3. Draw a small table like the ones in Carey's *Enquiry* with three columns: Country, People, Religion. Fill in one row for your own country.

From history. On March 11, 1812, a fire swept through the printing office at Serampore. Type, paper and years of manuscripts burned, including much of a large dictionary Carey had been writing. Carey walked through the ashes and grieved, then started again. The type metal was dug out of the ruins and recast, and within months the presses were running. When news of the fire reached Britain and America, Christians gave so generously that the loss was soon made up.

WORKED EXAMPLES

Example 1. Carey's ship sailed on June 13, 1793, and the family landed at Calcutta on November 11, 1793. How many days did the voyage take? About how many months is that?

(Use the map or drawing "Carey's voyage, 1793." shown earlier in this lesson.)

1. June has 30 days. From June 13 to June 30 is $30 - 13 = 17$ days.
2. Add the full months: July 31, August 31, September 30 and October 31 days. That is $31 + 31 + 30 + 31 = 123$ days.
3. Add the 11 days of November: $17 + 123 + 11 = 151$ days.
4. A month is about 30 days, and $151 \div 30$ is about 5.

Answer: About 151 days, or about 5 months.

Example 2. On the map, London is at about 52°N, the Cape of Good Hope at about 34°S, and Calcutta at about 23°N. How many degrees of latitude did the ship cross going south from London to the Cape and then north from the Cape to Calcutta? Each degree of latitude is about 69 miles (111 km). About how many miles of north-south travel is that?

1. From 52°N down to the equator is 52 degrees. From the equator down to 34°S is 34 more. So London to the Cape is $52 + 34 = 86$ degrees.
2. From 34°S up to the equator is 34 degrees, and from the equator up to 23°N is 23 more. So the Cape to Calcutta is $34 + 23 = 57$ degrees.
3. Total: $86 + 57 = 143$ degrees of latitude.
4. Multiply by 69 miles: $143 \times 69 = 9,867$ miles.

Answer: 143 degrees of latitude, about 9,900 miles (about 15,900 km) of north-south travel alone, before counting any east-west sailing.

PRACTICE

1. **EASY** What were the two points of William Carey's famous sermon at Nottingham in 1792?
2. **EASY** Around which cape at the southern end of Africa did Carey's ship sail on the way to India?
3. **EASY** Calcutta is at about 23°N, 88°E. Is it north or south of the equator? Is it east or west of the prime meridian?
(Use the map or drawing "Use the grid lines to check your answer." shown earlier in this lesson.)
4. **MEDIUM** Carey reached India in 1793 and died at Serampore in 1834 without ever going back to England. How many years did he live in India?
5. **MEDIUM** Why did Carey sail to India on a Danish ship instead of an English one, and why did he later settle at Serampore?
6. **MEDIUM** In Carey's *Enquiry*, what three kinds of facts did he list for each country of the world?
7. **HARD** In Unit 3 you learned that each hour of time difference equals 15 degrees of longitude. Calcutta is at about 88°E and London at 0°. About how many hours earlier does the sun reach noon in Calcutta than in London?
8. **CHALLENGE** Write three or four sentences: How did knowing geography help William Carey plan his mission? Give at least two examples from the lesson.

COMMON MISTAKES

- Thinking ships sailed straight from England to India. Africa was in the way, so they went far south around the Cape of Good Hope; the Suez Canal did not open until 1869.
- Adding latitudes wrongly across the equator. To go from a northern latitude to a southern one, add the two numbers (52°N to 34°S is 86 degrees), do not subtract.

- Telling Carey's story as if it were all success. His family suffered greatly, and his first years in India were full of loss; telling the truth about the hard parts makes his perseverance clearer.

Make it a game • Carey's Wall Map. One player names a country. The other players race to find it on a globe or world map, point to it, and say whether it is in the Northern or Southern Hemisphere and the Eastern or Western Hemisphere. The first to point correctly earns a point; earn a bonus point by naming one language spoken there. After ten countries, the winner gets to place a star sticker on the class wall map.

Scripture. "Enlarge the place of thy tent, and let them stretch forth the curtains of thine habitations: spare not, lengthen thy cords, and strengthen thy stakes; For thou shalt break forth on the right hand and on the left; and thy seed shall inherit the Gentiles, and make the desolate cities to be inhabited." (Isaiah 54:2-3, KJV)

This was Carey's text at Nottingham in 1792. A tent that is enlarged needs longer cords and stronger stakes. Carey believed the church should stretch its cords out to the whole map of the world.

Practice answers

1. Expect great things from God; attempt great things for God.
2. The Cape of Good Hope.
3. North of the equator and east of the prime meridian.
4. $1834 - 1793 = 41$ years.
5. The British East India Company did not want missionaries in its lands, so he could not get passage on an English ship. Serampore was a Danish town, where the missionaries were allowed to live, preach and print.
6. Its size (length and breadth in miles), its number of inhabitants, and its religion.
7. $88 \div 15$ is about 5.9, so about 6 hours (more exactly, about 5 hours 52 minutes). Calcutta is east, so noon comes there first.
8. Answers will vary. Strong answers mention that his wall map and the tables in his *Enquiry* showed where people lived, how many there were and what they believed, so he could see where the gospel had not gone; that he had to know the sea route around the Cape of Good Hope and how long it would take; and that he had to learn the languages of India (such as Bengali) to translate the Bible.

6.2 DAVID LIVINGSTONE CROSSES AFRICA ★

OBJECTIVES

- Tell the story of David Livingstone's walk across south-central Africa (1853–1856) and his first sight of Victoria Falls in November 1855.
- Trace his route on a map from Linyanti to Luanda on the Atlantic and then to Quelimane on the Indian Ocean, and measure distances using degrees of latitude.
- Explain how Livingstone fixed positions by the sun, the stars and his watch, and judge his life honestly: his courage and his fight against the slave trade, and his failures.

Warm-up. Fill a clear jar halfway with water, put on the lid, and shake it hard over a dark sheet of paper in bright light, or spray a fine mist from a spray bottle in a sunny window. Look for drops hanging in the air and maybe a small rainbow. Now imagine a cloud of spray like that rising over a thousand feet high, so tall you could see it from miles away. That is what David Livingstone saw before he ever saw the waterfall.

Watch. *Following Livingstone's Trail to the "Smoke That Thunders"* (Secrets of the Dead PBS, 2:01). <https://www.youtube.com/watch?v=kj4-17FSqcA>

After the story: watch this two-minute clip that follows Livingstone's route to Victoria Falls, Mosi-oa-Tunya, "the smoke that thunders," and notes his skill as a mapmaker.

Note: Transcript checked. It mentions Livingstone's hope of opening Central Africa to trade.

Backup video. *10th November 1871: Henry Morton Stanley locates Dr David Livingstone* (HistoryPod, 3:03). <https://www.youtube.com/watch?v=gV5oexwbn2c>

As review: watch the story of how Henry Morton Stanley found Livingstone at Ujiji in 1871. Note: Captions were not available to check; preview it first.

KEY TERMS

Mosi-oa-Tunya

The local name for Victoria Falls, meaning "the smoke that thunders."

gorge

A deep, narrow valley with steep rock walls, often cut by a river.

watershed

High ground that separates rivers flowing one way from rivers flowing another way.

lunar distance

The angle between the moon and a star or the sun, measured with a sextant; with tables, it tells the time at Greenwich and so the longitude.

slave trade

The capturing, buying and selling of people as property. In Livingstone's day, slave traders still marched captives from the interior of Africa to the east coast.

porter

A person hired to carry loads on a journey, usually on the head or shoulders.

CORE IDEAS

The story. In November 1855, David Livingstone was paddled down the Zambezi River in a canoe by Makololo boatmen. Ahead of him, columns of white vapor rose from the river into the sky, and he could hear a steady roar. The local people called the place **Mosi-oa-Tunya**, “the smoke that thunders.” The boatmen landed him on a small island right at the edge of the falls. He crept to the lip, looked over, and saw the whole broad river plunge into a narrow crack in the earth. He named the falls after Queen Victoria. Later he wrote that it had never been seen before by European eyes, “but scenes so lovely must have been gazed upon by angels in their flight.”

Who he was. Livingstone was born in 1813 in Blantyre, Scotland. At ten he went to work in a cotton mill from six in the morning until eight at night, and he propped a Latin book on the spinning machine to study as he worked. He trained as a doctor and went to southern Africa in 1841 with the London Missionary Society. He soon pushed north beyond the other mission stations, across the edge of the Kalahari Desert, and in 1851 he reached the upper Zambezi. There he saw something that troubled him: slave traders were coming in from both coasts to buy captives. He believed that if a good road to the sea could be opened for honest trade, the slave trade could be starved out.

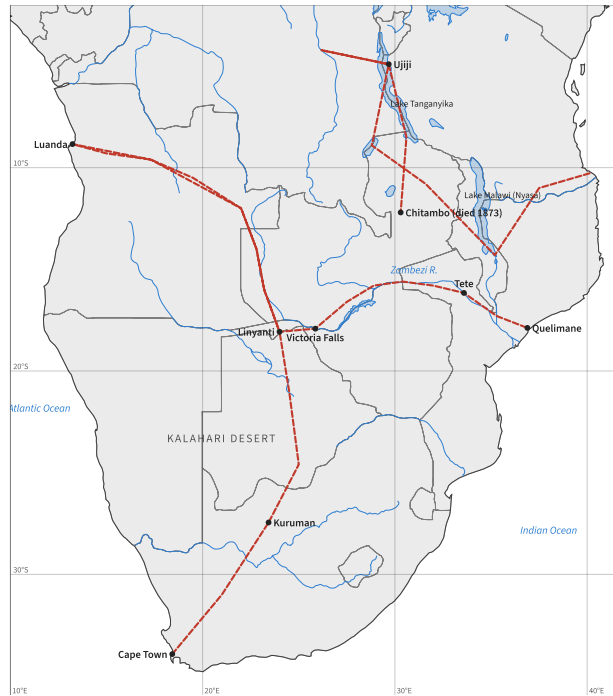
The crossing. So in November 1853 he set out from Linyanti, the town of the Makololo chief Sekeletu, with twenty-seven Makololo men. They went north up the Zambezi and then west through forests, swamps and rivers, and on May 31, 1854, they reached Luanda on the Atlantic coast. Livingstone was sick with fever and could have sailed home, but he had promised to bring his men back. They walked back to Linyanti, then followed the Zambezi east, past Victoria Falls, and reached Quelimane on the Indian Ocean in May 1856. He was the first European known to cross Africa from coast to coast. (Two African traders working for the Portuguese had crossed from Angola to Mozambique and back some fifty years earlier, but their journey was little known in Europe.)

How he figured it out. Livingstone did not just walk; he measured. At the Cape, the astronomer Thomas Maclear had taught him to use a sextant. On clear nights he measured the height of stars to find his **latitude**, and he measured **lunar distances** and timed them with his watch to work out his **longitude**, the problem you studied in Unit 3. He sent his notebooks to Maclear, who checked the numbers. Because of this, the maps Livingstone sent home put rivers, lakes and towns in their true places for the first time on European maps. The Royal Geographical Society gave him its gold medal, and his book *Missionary Travels and Researches in South Africa* (1857) was read by tens of thousands.

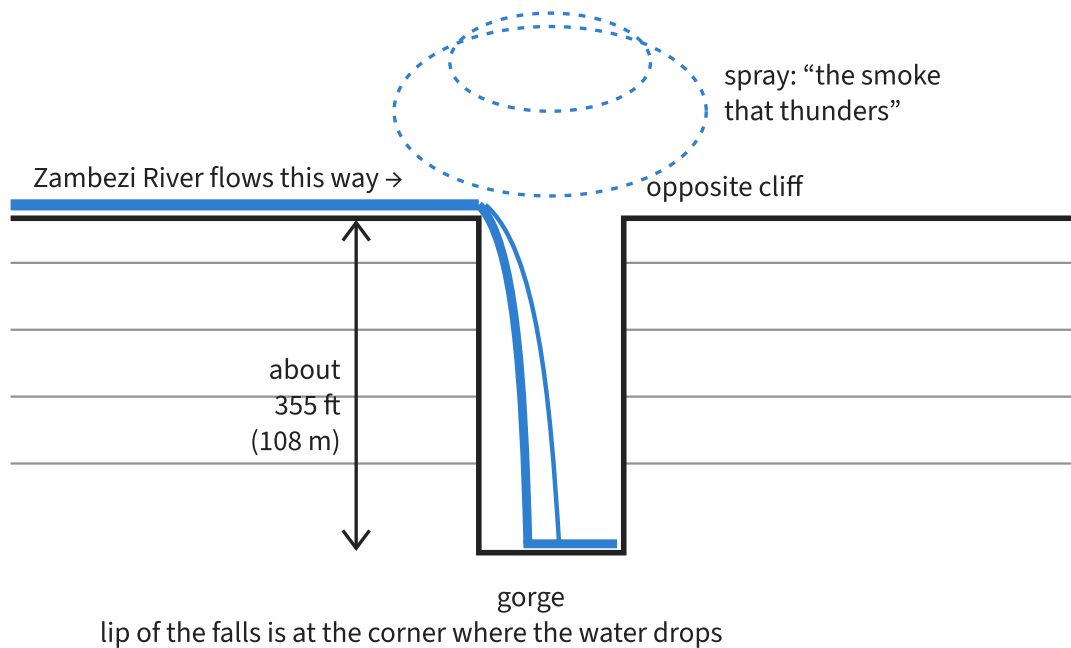
Told honestly. Livingstone was brave, tireless and kind to Africans, and he hated the slave trade. In 1871 at Nyangwe he watched slave traders shoot down hundreds of people in a crowded market, and his report shocked Britain; in 1873 the Sultan of Zanzibar was pressed to close the great slave market there. But Livingstone also failed. His later Zambezi

Expedition was a disaster: the river was blocked by rapids he had not seen, his wife Mary died of fever in 1862, and he quarreled with and unfairly dismissed some of his companions. His children grew up hardly knowing him. And his journeys were only possible because of African guides, boatmen and porters whose names are mostly forgotten.

On the map. Look at the map of Livingstone's journeys. Linyanti lies at about 18°S. Luanda lies at about 9°S, on the Atlantic. Victoria Falls is at about 18°S, 26°E, and Quelimane is at about 18°S, 37°E, on the Indian Ocean. Notice how his route follows rivers: rivers were the roads of Africa, and the Zambezi was the road he hoped would carry honest trade into the heart of the continent.



Livingstone's journeys across Africa (routes simplified).



A side view of Victoria Falls. The river drops into a narrow crack in the rock, and the spray rises high above it.

PICTURE STUDY



The Great Western (or Main) Fall, from Tressil Cliff to Garden Island, Thomas Baines, Published 1865 (from sketches made at the falls in 1862) · Colour lithograph by Day & Son, London, from Baines's sketches and paintings · Published in Baines's folio The Victoria Falls, Zambesi River, Sketched on the Spot (London, 1865), dedicated to the Royal Geographical Society. The Royal Geographical Society, London, also holds many of his oil paintings and watercolours of the falls.

Thomas Baines was an English artist and explorer who spent most of his life in southern Africa. In 1858 he joined Livingstone's Zambezi Expedition as its artist and storekeeper, but

in 1859 Livingstone dismissed him after Livingstone's brother Charles accused him of misusing the stores. Baines denied it, and most historians now think he was treated unfairly. He did not give up. In 1862 he traveled with the hunter James Chapman to the Victoria Falls and spent days sketching them from many angles.

From those sketches Baines made some of the first pictures of the falls that people in Europe ever saw. In 1865 a London printer turned ten of them into colour prints, and this is one of them. Baines drew carefully, almost like a map maker, so that people could see the shape of the gorge, the height of the spray and the rainbows in the mist.

Look closely

- Find the edge where the river drops. Is the water falling as one sheet or as many separate falls?
- Find the spray. Where is it thickest? Can you find a rainbow?
- Look for people or animals in the painting. How do they help you judge how big the falls are?
- Where was Baines standing when he painted this? Above the falls, beside them, or below?

Talk about it

1. Why would a painting like this have been important to people in Britain in the 1860s, before photographs of the falls were common?
2. Baines was treated unfairly by Livingstone, yet he kept exploring and painting. What does that tell you about him?
3. How is a painting of a place like a map, and how is it different?

PROJECT: A MISSIONARY JOURNEY MAP, PART 2: LIVINGSTONE'S CROSSING AND A LETTER FROM THE FALLS

Add Livingstone's great crossing of Africa to your unit journey map, with a small picture of Victoria Falls, and write a letter home from the falls. Then build a model to see how the falls drop into a crack in the earth.

You will need

- Your journey map from Lesson 6.1
- Colored pencils, a fine black pen and a blue pencil
- Lined paper for the letter
- For the model: a shallow baking tray, two bricks of modeling clay or play dough, a small cup of water, a spray bottle

Steps

1. On your journey map, find Africa. Mark Linyanti (about 18°S, 24°E), Luanda (about 9°S, 13°E), Victoria Falls (about 18°S, 26°E) and Quelimane (about 18°S, 37°E).

2. Draw the Zambezi River in blue from the middle of Africa to the Indian Ocean.
3. In a new color, draw Livingstone's route: Linyanti north and west to Luanda, back to Linyanti, then east along the Zambezi past the falls to Quelimane. Add arrows and the dates 1853 and 1856.
4. Draw a tiny picture of the falls with a cloud of spray beside the route, and label it Mosi-oa-Tunya.
5. Write a letter home of about eight sentences, dated November 1855, as if you were one of the Makololo boatmen or Livingstone himself. Describe the smoke, the roar and the view from the edge.
6. Model: press the clay flat in the tray to make a plateau. With a butter knife, cut a straight narrow crack across it, about an inch wide and as deep as the clay. Slowly pour water across the flat clay toward the crack and watch it fall in. Then mist the crack with the spray bottle to make the "smoke."

Tips

- Victoria Falls is unusual: the river does not fall off the end of a cliff into an open valley, it falls into a narrow crack that runs across its path. Make your model crack run across the river, not along it.
- Livingstone's routes in this lesson are simplified. Real paths wandered from village to village.

Check your work

- My map shows Livingstone's crossing from the Atlantic to the Indian Ocean with places and dates.
- My letter describes the falls with real details from the lesson.
- I can explain with my model why the spray rises out of the gorge.

MAP NOTEBOOK

1. Draw the side view of Victoria Falls from the lesson diagram and label: Zambezi River, lip, gorge, spray, about 355 feet.
2. Draw Livingstone's sextant and watch and write one sentence about what each was used for.
3. Make a two-column chart titled "Livingstone, Told Honestly" with the headings Courage and Good Deeds and Failures and Wrongs. Write at least two items in each.

From history. In 1866 Livingstone went back to Africa to search for the sources of the Nile, and for years no news of him reached Britain. In 1871 the reporter Henry Morton Stanley found him at Ujiji on Lake Tanganyika and is said to have greeted him with the words "Dr. Livingstone, I presume?" Livingstone would not go home. He died at Chitambo's village, near Lake Bangweulu in today's Zambia, on May 1, 1873. His African companions, led by Susi and Chuma, buried his heart under a tree there, dried his body,

and carried it for many months to the coast at Bagamoyo. He was buried in Westminster Abbey in London in April 1874.

WORKED EXAMPLES

Example 1. Linyanti is at about 18°S . Luanda is at about 9°S . How far north is Luanda from Linyanti, counting only the north-south distance? (Each degree of latitude is about 69 miles, or 111 km.)

(Use the map or drawing “Find Linyanti and Luanda on the map.” shown earlier in this lesson.)

1. Both places are south of the equator, so subtract: $18 - 9 = 9$ degrees of latitude.
2. Luanda has the smaller southern latitude, so it is closer to the equator, which means it is north of Linyanti.
3. Multiply: $9 \times 69 = 621$ miles. In kilometers: $9 \times 111 = 999$ km.

Answer: About 620 miles (about 1,000 km) north. Livingstone’s winding path through swamps and forests was much longer than that, and it took him from November 1853 to May 31, 1854.

Example 2. Victoria Falls is about 5,600 feet wide and about 355 feet high. (a) About how many miles wide is it? (One mile is 5,280 feet.) (b) The Statue of Liberty, from the ground to the tip of the torch, is about 305 feet tall. How much higher is the drop of the falls?

(Use the map or drawing “The drop of Victoria Falls.” shown earlier in this lesson.)

1. (a) 5,600 is a little more than 5,280, so the falls are a little more than 1 mile wide. ($5,600 \div 5,280$ is about 1.06.)
2. (b) Subtract: $355 - 305 = 50$ feet.

Answer: (a) About 1 mile wide (about 1.7 km). (b) The falls drop about 50 feet farther than the height of the Statue of Liberty with its pedestal.

PRACTICE

1. **EASY** What did the local people call Victoria Falls, and what does the name mean?
2. **EASY** Livingstone’s crossing reached two coasts. On which ocean is Luanda? On which ocean is Quelimane?
(Use the map or drawing “Livingstone’s journeys across Africa.” shown earlier in this lesson.)
3. **EASY** Victoria Falls is at about 18°S , 26°E . Is it in the Northern or Southern Hemisphere? The Eastern or Western Hemisphere?
4. **MEDIUM** Livingstone left Luanda in September 1854 and reached Quelimane in May 1856. About how many months did the journey back across Africa take?

5. **MEDIUM** Luanda is at about 13°E and Quelimane at about 37°E. How many degrees of longitude lie between them?
6. **HARD** The earth turns 15 degrees every hour, so it turns 1 degree every 4 minutes. If Livingstone's watch was 4 minutes wrong when he worked out his longitude, how far off would his longitude be? Near Victoria Falls, one degree of longitude is about 65 miles. How many miles off would his map be?
7. **HARD** Livingstone did not cross Africa alone. Name the people who went with him from Linyanti to Luanda, who sent them, and what Livingstone did that shows he kept faith with them.
8. **CHALLENGE** Write four or five sentences judging David Livingstone honestly. Name at least two things he did well and two ways he failed or did wrong.

COMMON MISTAKES

- Saying Livingstone “discovered” Victoria Falls as if no one knew about it. The people who lived there had known and named it for centuries; Livingstone was the first European to see it and put it on a European map.
- Mixing up southern latitudes. In the Southern Hemisphere a bigger number is farther south, so 18°S is south of 9°S.
- Telling only the heroic parts. Livingstone was brave and good in many ways, but his later expedition failed, his family paid a heavy price, and his success depended on African companions.

Make it a game · Smoke That Thunders Relay. Lay out a long path across the room or yard with pillows or chalk for Linyanti, Luanda, Victoria Falls and Quelimane. Players carry a “load” (a book on the head, like a porter) from station to station. At each station they must answer a card before going on: its latitude, which ocean is nearby, or a fact from the lesson. A wrong answer means one step back. The first team to reach Quelimane on the Indian Ocean wins.

Scripture. “Teaching them to observe all things whatsoever I have commanded you: and, lo, I am with you alway, even unto the end of the world. Amen.” (Matthew 28:20, KJV)

In January 1856, near the Zambezi, Livingstone feared his party would be attacked. He read this verse and wrote in his journal that it was the word of a gentleman of the strictest honor, and he would not run away by night. Instead, he wrote, he would take his observations for latitude and longitude that evening, though they might be his last. The next day his party crossed the river in peace.

Practice answers

1. Mosi-oa-Tunya, “the smoke that thunders.”
2. Luanda is on the Atlantic Ocean. Quelimane is on the Indian Ocean.
3. Southern Hemisphere and Eastern Hemisphere.

4. September 1854 to September 1855 is 12 months, and September 1855 to May 1856 is 8 more, so about 20 months.
5. $37 - 13 = 24$ degrees of longitude.
6. 4 minutes of time is 1 degree of longitude, so his longitude would be 1 degree off, about 65 miles (about 105 km) east or west of the true place. That is why he checked his watch with lunar distances.
7. Twenty-seven Makololo men, sent by their chief Sekeletu. When Livingstone reached Luanda sick with fever, he refused to sail home and walked back with them to Linyanti, because he had promised to bring them home.
8. Answers will vary. Did well: crossed Africa from coast to coast with great courage; fixed places carefully by latitude and longitude so that his maps were accurate; treated Africans with respect and kept his promise to the Makololo; exposed the slave trade (Nyangwe, 1871) and helped bring about the closing of the Zanzibar slave market. Failed or did wrong: the Zambezi Expedition went badly because he misjudged the river; his wife died on that expedition and his children grew up without him; he quarreled with and unfairly dismissed companions such as Thomas Baines; he made few lasting converts himself.

6.3 HUDSON TAYLOR AND INLAND CHINA

OBJECTIVES

- Tell how Hudson Taylor sailed to China in 1853, adopted Chinese dress, and founded the China Inland Mission in 1865 to reach the inland provinces.
- Use a map of China to follow the Yangtze River inland and compare a straight-line distance with a river distance.
- Explain honestly how the opium trade and the treaties that ended the Opium Wars shaped where missionaries could go.

Warm-up. Lay a long piece of string along a winding path from one side of a room to the other: around a chair, under a table, past a door. Mark where it ends. Now stretch the same string straight between the two ends. How much string is left over? Rivers wind like that path, and in China in the 1800s, travelers went inland by river. Keep the string for the worked example.

Watch. *Our Story Begins - The history of the China Inland Mission and OMF International* (OMF International, 3:29). <https://www.youtube.com/watch?v=eZZfxzk464s>
After the story: Watch how Hudson Taylor's decision on Brighton beach in 1865 grew into the China Inland Mission, and listen for how the mission reached China's inland provinces.

Note: Captions were not available to check; preview it first. This is the mission's own short history video, so the last part covers OMF's work today, beyond the 1800s China in the lesson.

KEY TERMS

province

One of the large parts into which a country is divided, each with its own capital. China in the 1800s had 18 provinces in its heartland.

interior

The inland part of a country, far from the coast.

treaty port

A Chinese port city that China was forced by treaty to open to foreign traders and residents in the 1800s, such as Shanghai.

Yangtze River

China's longest river, about 3,900 miles (6,300 km) long, flowing east across the middle of China to the sea at Shanghai.

opium

A habit-forming drug made from poppies. British merchants shipped it from India and sold it in China in the 1800s, doing great harm.

CORE IDEAS

The story. On June 25, 1865, a tired young doctor named James Hudson Taylor walked alone on the beach at Brighton, on the south coast of England. For nearly five years he had been home from China, sick and worn out, and every day he had studied a map of China on his wall. He knew that eleven of China's eighteen provinces, with millions of people, did not have a single Protestant missionary. That morning on the sand he prayed for twenty-four willing and skillful workers: two for each of the eleven provinces and two more for Mongolia. Two days later he opened a bank account with ten pounds in the name of the **China Inland Mission**.

Who he was. Taylor was born in 1832 in Barnsley, Yorkshire, the son of a chemist and Methodist preacher. As a teenager he decided to go to China, and he studied medicine and Chinese to get ready. He sailed from Liverpool on September 19, 1853, and reached Shanghai on March 1, 1854. Most missionaries then lived in a few port cities, wore European clothes and lived much as they did at home. Taylor did something many of them thought foolish. In 1855 he put on Chinese clothes and wore his hair in a long braid like Chinese men, so that crowds would listen to his message instead of staring at the strange foreigner.

Told honestly. Why were foreigners allowed into China at all? The answer is not a happy one. British merchants were selling **opium**, a harmful drug grown in India, in China. When the Chinese government tried to stop it, Britain went to war, in the Opium Wars of 1839–1842 and 1856–1860. The treaties that ended those wars forced China to open **treaty ports** like Shanghai and, after 1860, to let foreigners travel inland. Missionaries used those treaties to go inland, and many Chinese people understandably saw them as part of the same foreign pressure. Hudson Taylor called the opium trade a great wrong and spoke against it for years.

How they figured it out. In May 1866 Taylor sailed back to China on the *Lammermuir* with his wife Maria, their four children and sixteen new missionaries. The China Inland Mission sent workers up the great rivers by boat and across country by mule, cart and wheelbarrow, into provinces where few Westerners had ever traveled. Europeans of the 1800s had good charts of China's coast, but for the inland provinces they relied mostly on Chinese maps and on an atlas made by Jesuit missionaries for the Kangxi Emperor in the early 1700s. Mission travelers wrote down the towns, rivers, roads and dialects they found, and some of their reports were printed for geographers. In 1877 one of them, John McCarthy, walked all the way across China into Burma.

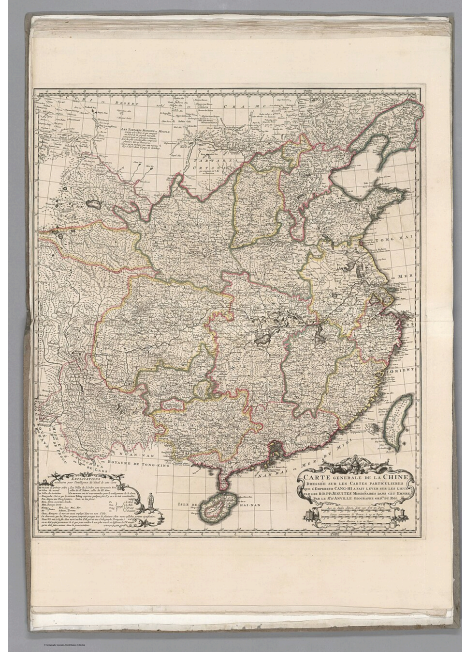
On the map. Look at the map of the Yangtze. Shanghai, at about 31°N, 121°E, sits near the river's mouth. Ocean steamers could go about 600 miles upstream to Hankou (today part of Wuhan). Above Yichang the river runs through the Three Gorges, where boats had to be hauled up the rapids by teams of men pulling on ropes. Far upstream is Chongqing, at about 30°N, 107°E. The Yangtze was the highway into inland China, just as the Zambezi was Livingstone's hoped-for highway into Africa.

The big idea. Taylor believed that God's work done in God's way would never lack God's supply, so the mission never asked anyone for money. It grew and grew. When Taylor died at Changsha, the capital of Hunan Province, in 1905, the China Inland Mission had more than 800 missionaries working with Chinese Christians in provinces all across China. The map on his study wall had been filled in, one province at a time.



Inland China and the Yangtze River route (the red line follows the river from Shanghai to Chongqing).

PICTURE STUDY



General map of China, from the Jesuit surveys, Jean-Baptiste Bourguignon d'Anville, from surveys made by Jesuit missionaries for the Kangxi Emperor, 1735 (in Du Halde's *Description of China*), reissued in the *Nouvel atlas de la Chine*, 1737 · Engraved map on paper, hand-coloured in outline · Copies are held in many map libraries around the world; this copy is from the 1737 Hague edition in the David Rumsey Map Collection, Stanford University

Between about 1708 and 1717, Jesuit missionaries working for the Kangxi Emperor of China, together with Chinese surveyors, traveled across the empire measuring latitudes and longitudes and drawing the rivers and roads. It was one of the largest map-making projects in the world at that time. The emperor kept the maps, but copies were sent to Europe, and the French geographer d'Anville turned them into printed maps.

For more than a hundred years, these were the best maps of inland China that Europeans had. When Hudson Taylor studied China, maps that went back to this survey were still in use, though many details far inland were out of date or missing.

Look closely

- Find the Great Wall in the north. How did the engraver draw it?
- Find the two great rivers, the Yellow River in the north and the Yangtze in the middle. Which way do they flow?
- Look at the coast and then at the far west. Which part of the map has more towns and details?
- Find the lines of latitude and longitude. Why would surveyors who measured latitude make a more trustworthy map?

Talk about it

1. These maps were made by missionaries and Chinese surveyors working together for a Chinese emperor. What does that tell you about how geography knowledge is shared?
2. Why might a map made in the early 1700s be less useful to a traveler in the 1870s?
3. If you were going to walk into a province where this map showed few details, what would you want to write down as you went?

PROJECT: A MISSIONARY JOURNEY MAP, PART 3: UP THE YANGTZE AND A LETTER FROM INLAND CHINA

Add Hudson Taylor's voyage to China and a river journey up the Yangtze to your unit journey map. Then write a letter home from a riverboat in the Three Gorges.

You will need

- Your journey map from Lessons 6.1 and 6.2
- Colored pencils, a blue pencil and a fine black pen
- A piece of yarn or string about 12 inches long
- Lined paper for the letter

Steps

1. On your map, mark Shanghai (about 31°N, 121°E) and Chongqing (about 30°N, 107°E).
2. Draw the sea route Hudson Taylor took in 1853–1854: from England south around the Cape of Good Hope, across the Indian Ocean, and north through the South China Sea to Shanghai. Use a new color and label it with the dates.
3. Draw the Yangtze River in blue from Chongqing to the sea at Shanghai. Make it wind, as real rivers do. Mark Hankou and Yichang along it.
4. Lay the yarn along your winding river from Chongqing to Shanghai, then stretch it straight between the two cities. Write on your map which is longer and about how many times longer.
5. Write a letter home of about eight sentences, dated 1870s, as if you were a China Inland Mission worker on a boat being hauled up the rapids of the Three Gorges. Tell what you see, what you wear and how the boatmen pull the boat.

Tips

- Taylor's sea route goes around the Cape of Good Hope too, because the Suez Canal did not open until 1869. It shares the first part of Carey's route, so you can draw it close beside Carey's line.
- Label lightly at first; Asia gets crowded on a world map.

Check your work

- My map shows Taylor's sea route and the Yangtze River with at least three cities.
- I measured the winding river and the straight line with yarn and wrote what I found.
- My letter uses real details of travel in inland China.

MAP NOTEBOOK

1. Draw Hudson Taylor in Chinese clothes and write one sentence explaining why he chose to dress that way.
2. Draw a river boat being hauled up a rapid by a line of men pulling a long rope from the bank. Label the river, the boat, the rope and the trackers.
3. Draw a simple outline of China and shade the middle part where the Yangtze flows. Write “Yangtze, about 3,900 miles” beside it.

From history. In the summer of 1900, during the Boxer Uprising in northern China, mobs and soldiers attacked foreigners and Chinese Christians. Fifty-eight missionaries of the China Inland Mission and twenty-one of their children were killed, along with many thousands of Chinese believers. Afterward, foreign governments forced China to pay large sums in damages. Hudson Taylor, old and ill, and the leaders of the mission refused to take any payment for their losses, wanting to show the Chinese people the gentleness of Christ.

WORKED EXAMPLES

Example 1. Hudson Taylor sailed from Liverpool on September 19, 1853, and reached Shanghai on March 1, 1854. How many days was he at sea? (1854 was not a leap year.)

1. September has 30 days. From September 19 to September 30 is $30 - 19 = 11$ days.
2. Add the full months: October 31, November 30, December 31, January 31, February 28. That is $31 + 30 + 31 + 31 + 28 = 151$ days.
3. Add 1 day for March 1: $11 + 151 + 1 = 163$ days.

Answer: 163 days, about $5\frac{1}{2}$ months.

Example 2. Shanghai is at about 31°N, 121°E. Chongqing is at about 30°N, 107°E. (a) How many degrees of longitude apart are they? (b) Near 30°N, one degree of longitude is about 60 miles. About how far apart are they in a straight line, going east-west? (c) By river up the Yangtze, Chongqing is about 1,500 miles (2,400 km) from Shanghai. About how many times longer is the river route?

(Use the map or drawing “Compare the straight line from Shanghai to Chongqing with the winding river route” shown earlier in this lesson.)

1. (a) Both are east longitudes, so subtract: $121 - 107 = 14$ degrees.
2. (b) Multiply: $14 \times 60 = 840$ miles. (Their latitudes differ by only 1 degree, so the straight line runs nearly due east-west.)
3. (c) Divide: $1,500 \div 840$ is about 1.8.

Answer: (a) 14 degrees of longitude. (b) About 840 miles (about 1,350 km). (c) The river route is almost twice as long as the straight line, because the river winds.

PRACTICE

1. **EASY** In what year did Hudson Taylor start the China Inland Mission, and where was he when he prayed for the first twenty-four workers?
2. **EASY** Why did Hudson Taylor wear Chinese clothes and a long braid?
3. **EASY** China’s heartland had 18 provinces. In 1865, 11 of them had no Protestant missionary. How many provinces had at least one?
4. **MEDIUM** Taylor prayed for 24 workers: two for each of the 11 provinces without a missionary, and two for Mongolia. Show that this adds up to 24.
5. **MEDIUM** The *Lammermuir* left London on May 26, 1866, and reached Shanghai on September 30, 1866. How many days was the voyage?
6. **MEDIUM** Suppose a sailing junk traveling up the Yangtze against the current made about 20 miles a day. About how many days would it take to go the 600 miles from Shanghai to Hankou?

(Use the map or drawing “The Yangtze River route.” shown earlier in this lesson.)

7. **HARD** The Yangtze is about 3,900 miles long. The Mississippi is about 2,340 miles long. How much longer is the Yangtze? Is it about one and a half times as long, or about three times as long?
8. **CHALLENGE** Write three or four sentences: How did the opium trade and the Opium Wars make it possible for missionaries to go inland, and why did that make their work harder? What did Hudson Taylor think of the opium trade?

COMMON MISTAKES

- Thinking Hudson Taylor was the first Christian in China. Christians had come to China centuries before, including Jesuits like Matteo Ricci around 1600, and Protestant

missionaries such as Robert Morrison from 1807. Taylor's new step was to go deliberately to the inland provinces.

- Thinking that no one had mapped inland China. Chinese map makers and the Jesuit survey for the Kangxi Emperor had mapped it; what Europeans lacked in Taylor's day were up-to-date, detailed maps of the interior.
- Comparing a straight-line distance with a river distance as if they were the same. A river route can be nearly twice as long as a straight line between the same two cities.

Make it a game • Province Hop. Draw a large simple map of China on the sidewalk in chalk (or tape it on the floor) with the Yangtze running across the middle and six cities on it: Shanghai, Nanjing, Hankou, Yichang, Chongqing and Changsha. Players start at Shanghai. Roll a die to move along the river from city to city; at each city answer a question from the lesson to stay. Rolling a 1 means "rapids in the gorge": lose a turn while the trackers pull your boat. The first player to reach Chongqing wins.

Scripture. "Yea, so have I strived to preach the gospel, not where Christ was named, lest I should build upon another man's foundation:" (Romans 15:20, KJV)

The apostle Paul wanted to go where the gospel had not yet been preached. Hudson Taylor looked at his map of China the same way, and the China Inland Mission went first to the provinces where there were no missionaries at all.

Practice answers

1. 1865, on the beach at Brighton, England.
2. So that Chinese people would listen to his message instead of staring at a strange foreigner, and to show respect by living like the people he served.
3. $18 - 11 = 7$ provinces.
4. $2 \times 11 = 22$, and $22 + 2 = 24$.
5. May 26 to May 31 is 5 days; June 30 + July 31 + August 31 + September 30 = 122 days; $5 + 122 = 127$ days (about 4 months).
6. $600 \div 20 = 30$ days, about a month.
7. $3,900 - 2,340 = 1,560$ miles longer. $3,900 \div 2,340$ is about 1.7, so it is about one and a half times as long (closer to one and three-quarters).
8. British merchants sold harmful opium in China, and when China tried to stop it Britain fought the Opium Wars. The treaties that ended the wars forced China to open ports and, after 1860, to let foreigners travel inland, so missionaries could go. But many Chinese people saw missionaries as part of the same foreign pressure, which made them distrust the missionaries. Taylor called the opium trade a great wrong and spoke against it.

6.4 MARY SLESSOR OF CALABAR

OBJECTIVES

- Tell how Mary Slessor, a mill girl from Dundee, Scotland, went to Calabar in West Africa in 1876 and lived among the peoples of the Cross River for nearly forty years.
- Compare the latitude, temperature and rainfall of Dundee and Calabar and explain why a rain forest lies near the equator.
- Describe honestly the real wrongs Mary Slessor fought, including the killing of twins, and the slave-trade history of Calabar.

Warm-up. Put a cup outside on a rainy day, or think of the rainiest day you remember. Now take a ruler and hold your hand flat at 10 inches from the table. Calabar, in Nigeria, gets about 10 inches of rain in an average month, and much more than that in the wettest months. Where you live, how many inches do you think fall in a whole month? Write down your guess and check it later.

Watch. *Christian Heritage Spotlight - Ep. 16 - Mary Slessor* (Crown Christian Heritage Trust, 3:10). <https://www.youtube.com/watch?v=D8k6yia3fYo>

After the story: Listen for Mary Slessor's path from the Dundee jute mill to Calabar, and her work rescuing twins in the rain forest of what is now Nigeria.

Note: Captions were not available to check; preview it first. The story of rescuing twins who were left to die may be hard for younger children.

KEY TERMS

rain forest

A thick, tall forest in a place that is warm all year and gets heavy rain in most months, such as southern Nigeria.

mangrove

A tree that grows in salty or muddy water along tropical coasts and river mouths, standing on tangled roots.

jute

A strong plant fiber, grown mostly in Bengal, that was spun and woven into sacks and rope in the mills of Dundee.

estuary

The wide mouth of a river where fresh river water meets salt water from the sea.

wet season

The part of the year when most of the rain falls. In Calabar it runs from about April to October.

CORE IDEAS

The story. In the 1860s, in the smoky city of Dundee, Scotland, a red-haired girl named Mary Slessor worked at a loom in a jute mill. She had started at the age of eleven as a “half-timer,” spending half the day in the mill and half in the mill school. Her father drank away much of the family’s money, and by her teens Mary was working full days to help feed her mother and sisters. She propped a book on her loom to read as she worked, and in the evenings she taught Sunday school to rough children in the poor streets nearby. When news came that David Livingstone had died in Africa, she made up her mind to go to Africa herself.

The journey. In August 1876, at the age of twenty-seven, Mary Slessor sailed from Liverpool for Calabar, on the coast of what is now southeastern Nigeria. The Calabar mission of the United Presbyterian Church of Scotland had been started in 1846 by Hope Waddell and a group of Christians from Jamaica, among them men and women who had once been enslaved. Mary learned the Efik language so well that people said she spoke it like one of them. She lived in a small house, ate the local food, often went barefoot, and caught malaria again and again, as nearly every missionary on that coast did. So many Europeans died of fever there that West Africa was called “the white man’s grave.”

Told honestly. Calabar’s history held real darkness. In the 1700s, Old Calabar had been one of the busiest slave-trading ports in Africa. Efik merchants sold captives from the interior to European ships, most of them British, which carried them across the Atlantic. Britain outlawed its slave trade in 1807, but cruel customs remained. Many people believed that twins were cursed, so twin babies were left in the forest to die and their mothers were driven out. When an important man died, some of his slaves might be killed to serve him in the next world. People accused of crimes were made to swallow poison beans to prove their innocence. Mary Slessor did not lecture from a distance. She took in abandoned twins and other children by the dozen, raised many of them as her own, and sat for hours with chiefs, arguing for mercy.

Into the forest. In 1888 she moved inland to Okoyong, a district of rain forest feared even by the people of Calabar, and she lived there alone among its villages. Over years she won the people’s trust. In 1892 the British government made her its official agent and judge for Okoyong, one of the first women to hold such a post in the British Empire. She held court under the trees, settling quarrels by common sense. Later she moved farther up the Cross River and its creeks, opening schools and mission stations. People called her “Ma,” or Mother. She died at Use, near Ikot Obong, on January 13, 1915, and was buried in Calabar.

On the map. Dundee lies at about 56°N. Calabar lies at about 5°N, 8°E, only about 340 miles north of the equator. Near the equator the sun is high overhead all year, so Calabar is hot in every month, about 80°F on average, while Dundee averages about 48°F. Warm, moist air rising over the land drops heavy rain, about 120 inches a year in Calabar against about 30 in Dundee. That steady heat and rain is why a tall **rain forest** covers the land, why **mangroves** crowd the **estuary** of the Cross River, and why the rivers and creeks were the roads Mary traveled by canoe.

The big idea. Geography shaped Mary Slessor's work at every step: the rivers she paddled, the fevers she suffered, the forest villages she walked to. A mill girl with little schooling became one of the best-known Christians in West Africa because she went where the need was and stayed.



Calabar and the Cross River, where Mary Slessor lived and worked from 1876 to 1915.

PICTURE STUDY



Mary Slessor with some of her adopted children, Unknown photographer, late 1800s or early 1900s (the archive dates it 'late 19th century') · Photograph, made into a coloured glass lantern slide for mission talks · Centre for the Study of World Christianity, University of Edinburgh (International Mission Photography Archive). The McManus, Dundee, also holds Mary Slessor's belongings and photographs.

Most pictures of explorers show them with guns, maps or flags. The best-known photographs of Mary Slessor show her with children. Many of them were twins or orphans she had rescued from the forest, and some grew up to help her in her work. Her first adopted daughter, Janie, was a twin she saved as a baby and kept with her all her life.

Look closely at a photograph like this the way a geographer looks at a map: the clothes, the buildings, the trees and the faces all tell you something about the place and the time.

Look closely

- Find Mary Slessor. How is she dressed? Does she look like a rich or important person?
- Look at the children. How many are there? Are they dressed in African or European clothing, or a mix?
- Look at the background. What can you tell about the climate from the plants or buildings?
- Look at the faces. How would you describe the mood of the photograph?

Talk about it

1. Why do you think Mary Slessor chose to be photographed with her children rather than alone?
2. What does this photograph tell you about what mattered most to her?

3. How is this picture different from the paintings and maps you studied earlier in the unit?

PROJECT: A MISSIONARY JOURNEY MAP, PART 4: MARY SLESSOR'S JOURNEY AND THE FINISHED MAP

Add Mary Slessor's journey from Scotland to Calabar to your unit journey map, write your last letter home, and finish the map with a legend and a title. Then compare the climates of Dundee and Calabar with a simple rain chart.

You will need

- Your journey map from Lessons 6.1 to 6.3
- Colored pencils, a fine black pen
- Graph paper and a ruler
- Lined paper for the letter

Steps

1. Mark Dundee, Scotland (about 56°N, 3°W) and Calabar (about 5°N, 8°E) on your map.
2. In a new color, draw Mary Slessor's sea route: south from Liverpool along the coast of West Africa and east into the Gulf of Guinea to Calabar. Label it with the date 1876.
3. Draw a small rain-forest tree and a canoe near Calabar.
4. Make a legend in a corner of your map: one colored line for each missionary (Carey, Livingstone, Taylor, Slessor), with the dates of each journey.
5. Give your map a title in your best lettering, such as "Missionaries as Geographers," and draw a compass rose.
6. On graph paper, make a bar graph with two bars: yearly rain in Dundee (about 30 inches) and in Calabar (about 120 inches). Let one square equal 10 inches.
7. Write a last letter home of about eight sentences, dated 1888, as if you were Mary Slessor writing to her mother from Okoyong. Tell about the forest, the rain, the children and the river.

Tips

- Calabar sits up a river mouth, not on the open beach. Draw it a little inland from the coast.
- Keep all four letters together in a folder or punch holes and tie them with string to make a booklet to go with your map.

Check your work

- My map shows four journeys in four colors with a legend, dates, a title and a compass rose.
- My bar graph compares the rainfall of Dundee and Calabar correctly.
- My four letters home tell real details from each missionary's journey.

MAP NOTEBOOK

1. Draw a mangrove tree standing on its tangled roots in the water, with a canoe passing by. Label roots, water and canoe.
2. Draw a loom in a Dundee mill on one side of the page and a forest village on the other. Write one sentence under each picture about Mary's life there.
3. Draw a thermometer for Dundee (about 48°F) and one for Calabar (about 80°F). Shade them to the right heights.

From history. Mary Slessor was buried in the mission cemetery in Calabar in January 1915, and the government officials of the colony gave her a funeral with honors. In Dundee, her old city, memorials and a museum collection remember her, and in 1997 her portrait was printed on a Scottish ten-pound banknote. In Nigeria, schools and streets bear her name, and Calabar people still speak of her as the mother who saved the twins.

WORKED EXAMPLES

Example 1. Dundee is at about 56°N. Calabar is at about 5°N. How far south is Calabar from Dundee, counting only the north-south distance? (One degree of latitude is about 69 miles, or 111 km.)

1. Both are north latitudes, so subtract: $56 - 5 = 51$ degrees.
2. Multiply by 69: $51 \times 69 = 3,519$ miles.
3. In kilometers: $51 \times 111 = 5,661$ km.

Answer: About 3,500 miles (about 5,700 km) south. The voyage by sea was longer, because ships followed the bulge of West Africa's coast.

Example 2. Calabar gets about 120 inches of rain a year. Dundee gets about 30 inches. (a) How many times as much rain falls in Calabar? (b) If Calabar's rain were spread evenly over 12 months, about how much would fall each month?

1. (a) Divide: $120 \div 30 = 4$.
2. (b) Divide: $120 \div 12 = 10$ inches a month. (Really, most of it falls in the wet season from about April to October, so those months get much more.)

Answer: (a) About 4 times as much. (b) About 10 inches a month on average.

PRACTICE

1. **EASY** What fiber did Mary Slessor weave in the mills of Dundee, and what was it used to make?
2. **EASY** Calabar lies at about 5°N. Why is it hot in every month of the year?

3. **EASY** Name one wrong custom Mary Slessor fought in Calabar and tell what she did about it.
4. **MEDIUM** Mary Slessor was born in December 1848 and sailed for Calabar in August 1876. How old was she when she sailed?
5. **MEDIUM** Calabar averages about 80°F and Dundee about 48°F. How much warmer is Calabar on average?
6. **MEDIUM** On the map, Itu is at about 5.2°N, 8.0°E, and Calabar is at about 5.0°N, 8.3°E. In which direction would Mary Slessor travel to go from Calabar up the river to Itu: northeast, northwest, southeast or southwest?
(Use the map or drawing "Calabar and the Cross River." shown earlier in this lesson.)
7. **HARD** Mary Slessor arrived in Calabar in 1876 and died in West Africa in 1915, with only a few visits home. About how many years did she serve in West Africa? About what fraction of her life of 66 years is that?
8. **CHALLENGE** Write four or five sentences: How did geography (latitude, climate, rivers and forest) shape Mary Slessor's life and work in Calabar? Use at least three facts from the lesson.

COMMON MISTAKES

- Thinking a rain forest is rainy only some of the time. In a place like Calabar it is warm all year and rains heavily in most months, though there is a drier season.
- Subtracting latitudes on opposite sides of the equator. Dundee (56°N) and Calabar (5°N) are both north, so you subtract; you only add when one is north and the other south.
- Telling the story of Calabar as if all the wrongs were on one side. Efik traders sold captives and European ships, mostly British, carried them away; later, cruel local customs and the fevers of the coast were both real, and Mary Slessor faced them all honestly.

Make it a game · Canoe up the Cross River. Lay a long blanket or rope on the floor as the Cross River, with paper stations for Calabar, Creek Town, Okoyong and Itu. Players "paddle" (sit on a towel and scoot) from station to station. At each station, draw a card with a question about one of the four missionaries in this unit: a date, a place, a latitude or a fact. A right answer lets you paddle on; a wrong answer means "a sudden storm, wait one turn." The first player to reach Itu wins and gets to name the next missionary journey the class will study.

Scripture. "Pure religion and undefiled before God and the Father is this, To visit the fatherless and widows in their affliction, and to keep himself unspotted from the world." (James 1:27, KJV)

Mary Slessor did exactly this. She took in babies left to die and mothers driven out of their villages, and she cared for them as family for the rest of her life.

Practice answers

1. Jute, which was woven into sacks, bags and rope.
2. It is close to the equator, so the sun is high in the sky all year round.
3. The killing of twin babies, who were left in the forest to die (or the killing of slaves at a chief's funeral, or the poison-bean ordeal). She rescued twins and other abandoned children, raised many as her own, and argued with chiefs for mercy.
4. 27 years old. (She would have turned 28 in December 1876.)
5. $80 - 48 = 32^{\circ}\text{F}$ warmer.
6. Northwest. Itu is a little farther north (higher latitude) and a little farther west (smaller east longitude).
7. $1915 - 1876 = 39$ years. 39 out of 66 is a little more than half of her life (about 6 out of 10 years).
8. Answers will vary. Strong answers mention that Calabar is near the equator (about 5°N), so it is hot all year; that it gets about 120 inches of rain, so thick rain forest and mangrove swamps cover the land; that the heat and wet brought malaria, which made her sick again and again; that rivers and creeks such as the Cross River were the roads, so she traveled by canoe; and that inland districts like Okoyong were hard to reach and cut off, which is why she had to go and live there.

UNIT 6 REVIEW

Answer each question. Show your work for calculations and use complete sentences for explanations. Use a world map or globe where a question asks for one. The review is worth 50 points.

1. (5 pts) Who was William Carey, and what were the two points of his famous sermon of 1792?
2. (5 pts) Carey sailed from England on June 13, 1793, and landed at Calcutta on November 11, 1793. How many days did the voyage take? Name the cape his ship sailed around.
3. (5 pts) London is at about 52°N and the Cape of Good Hope at about 34°S. How many degrees of latitude lie between them? About how many miles is that? (1 degree is about 69 miles.)
4. (5 pts) What is the local name for Victoria Falls, and what does it mean? About how high and how wide are the falls?
5. (5 pts) On the map of Livingstone's journeys, his crossing of Africa (1853-1856) started at Linyanti. Name the city where he reached the Atlantic and the town where he reached the Indian Ocean. Which great river did he follow to the east coast?
6. (5 pts) How did Livingstone find his latitude and longitude, and why were his maps more trustworthy because of it?
7. (5 pts) Name one great good that Livingstone did and one way he failed. Then name the people without whom his crossing of Africa could not have happened.
8. (5 pts) What was the China Inland Mission, when did Hudson Taylor start it, and why did he wear Chinese clothes?
9. (5 pts) Shanghai is at about 121°E and Chongqing at about 107°E, both near 30°N. How many degrees of longitude apart are they? By river they are about 1,500 miles apart; in a straight line about 840 miles. Why is the river route longer?
10. (5 pts) Dundee is at about 56°N and Calabar at about 5°N. (a) About how many miles apart are they north to south? (b) Calabar gets about 120 inches of rain a year and Dundee about 30. Use latitude to explain why Calabar is hot and rainy all year, and name one wrong custom Mary Slessor fought there.

UNIT PROJECT: A MISSIONARY JOURNEY MAP WITH LETTERS HOME

Finish the large world map you built through this unit. It should show four journeys in four colors: William Carey from England around the Cape of Good Hope to Calcutta (1793), David Livingstone across Africa from Luanda to Quelimane past Victoria Falls (1853-1856), Hudson Taylor to Shanghai and up the Yangtze (1853-1854 and after), and Mary Slessor from Liverpool to Calabar (1876). Mark each key place with its latitude and longitude, add a legend, a compass rose and a title, and draw small pictures along the routes.

With the map, include your four letters home, one for each journey, written as someone who was really there, and a short paragraph answering: How did geography shape these

missionaries' journeys, and what can we honestly praise and honestly regret in their stories?

- **Accuracy:** All four routes follow the right seas, capes and rivers, and the places are in the correct hemispheres with sensible latitudes and longitudes.
- **Letters home:** Each letter is dated, written in a believable voice, and uses at least three real details of the journey, place or climate.
- **Honest judgment:** The paragraph names real courage and good works and also real failures or wrongs of the time, using facts from the lessons.
- **Care:** The map is neat and readable, with a clear legend, title and compass rose, and the letters are bound or kept together with it.

Answer key

1. William Carey was an English shoemaker and Baptist pastor who studied the world map, helped start the Baptist Missionary Society, and went to India as a missionary in 1793. His two points: "Expect great things from God; attempt great things for God."
2. $17 (\text{June}) + 31 + 31 + 30 + 31 + 11 = 151$ days. The ship sailed around the Cape of Good Hope.
3. One is north and one is south, so add: $52 + 34 = 86$ degrees. $86 \times 69 = 5,934$, about 5,900 miles (about 9,500 km).
4. Mosi-oa-Tunya, "the smoke that thunders." The falls are about 355 feet (108 m) high and about a mile (1.7 km) wide.
5. He reached the Atlantic at Luanda and the Indian Ocean at Quelimane. He followed the Zambezi River east.
6. He measured the height of stars with a sextant to find latitude, and measured lunar distances and timed them with his watch to work out longitude. He sent his notes to the astronomer Thomas Maclear at the Cape, who checked them. Because the places were measured, not guessed, his maps put rivers, lakes and towns in their true positions.
7. Good (any one): crossed Africa with courage; made accurate maps; exposed the East African slave trade and helped bring about the closing of the Zanzibar slave market; kept his promise to bring his Makololo men home. Failure (any one): the Zambezi Expedition failed; his wife died on it and his children grew up without him; he unfairly dismissed companions such as Thomas Baines. People: the twenty-seven Makololo men sent by Chief Sekeletu, and other African guides, boatmen and porters.
8. It was a mission Taylor founded in 1865 to send missionaries into China's inland provinces, where there were none. He wore Chinese clothes and a braid so that people would listen to his message instead of staring at a foreigner, and to live like the people he served.
9. $121 - 107 = 14$ degrees of longitude. The river route is longer because the Yangtze winds back and forth instead of running in a straight line.
10. (a) $56 - 5 = 51$ degrees; $51 \times 69 = 3,519$, about 3,500 miles (about 5,700 km). (b) Calabar is near the equator, so the sun is high all year and the warm, moist air brings heavy rain, about 4 times as much as Dundee. Mary Slessor fought the killing of twin babies (also accept the killing of slaves at funerals or the poison-bean ordeal), rescuing twins and raising them as her own.

THE ENDS OF THE EARTH

By 1900 the coasts of the world had nearly all been charted, but three places still lay beyond reach: the North Pole on its frozen ocean, the South Pole on its high ice sheet, and the summit of the highest mountain. In this unit you will follow the explorers who went to the ends of the earth. You will cross the Arctic sea ice with Robert Peary, Matthew Henson and their four Inuit companions, ski to the South Pole with Roald Amundsen's dog teams, drift in the Weddell Sea with Ernest Shackleton's *Endurance*, and climb with Edmund Hillary and Tenzing Norgay to the top of Mount Everest.

These stories are full of courage, skill and careful planning, and also of hard questions. Did Peary truly reach the Pole? Why did Amundsen's men come home while Scott's did not? How did a navigator with a sextant find a small island across 800 nautical miles of stormy sea? You will use the rule that one degree of latitude is 60 nautical miles, draw polar-view maps, read an elevation profile and test which glove keeps the cold out best. Through it all, remember the psalmist: "In his hand are the deep places of the earth: the strength of the hills is his also" (Psalm 95:4).

BEFORE YOU BEGIN

- Can read latitude in degrees and minutes and knows that one degree of latitude is 60 nautical miles (Units 2 and 3)
- Knows what a sextant or quadrant measures and why navigators need an accurate clock
- Can add, subtract, multiply and divide whole numbers and count days between two dates
- Can find the poles, Antarctica, the Arctic Ocean, Greenland and the Himalaya on a globe

MASTERY CHECKLIST

- I can tell the stories of Peary and Henson, Amundsen, Shackleton, and Hillary and Tenzing, with their dates.
- I can explain the difference between the North Pole (on a frozen ocean) and the South Pole (on a high, ice-covered continent).
- I can draw a polar-view map and use degrees of latitude to find distances in nautical miles.
- I can explain why the claim that Peary reached the Pole is still debated and what kind of evidence settles such questions.
- I can explain why high places are cold and short of air, and read an elevation profile.
- I can design a fair test of insulation and explain why some materials keep in warmth better than others.

OPTIONAL BOOKS AND RESOURCES

- **Shackleton's *South* and Amundsen's *The South Pole* (free at Project Gutenberg)** (<https://www.gutenberg.org/ebooks/search/?query=shackleton+south>): Free. Shackleton's own account of the *Endurance* (1919) is a wonderful read-aloud in short passages, especially the chapters on the boat journey and the crossing of South Georgia. Search the same site for Amundsen's *The South Pole* and Matthew Henson's *A Negro Explorer at the North Pole* (1912).
- **Scott Polar Research Institute, University of Cambridge** (<https://www.spri.cam.ac.uk/>): Free to browse. The institute's museum and picture library hold diaries, maps, sledges and photographs from the polar expeditions in this unit.

7.1 PEARY AND HENSON NEAR THE NORTH POLE ★

OBJECTIVES

- Tell the story of Robert Peary, Matthew Henson and their four Inuit companions on the sea ice in the spring of 1909.
- Explain why the North Pole is a point on a frozen, drifting ocean and use the rule that one degree of latitude equals 60 nautical miles.
- Weigh the evidence for and against Peary's claim and explain why an explorer's claim must be something others can check.

Warm-up. Put an orange on the table and stick a toothpick straight down into the top. That is the North Pole. With a marker, draw four or five lines from the toothpick down the sides of the orange like the sections of the peel. These are lines of longitude. Now stand your finger on the toothpick and ask: if I walk away from this point in any direction, which way am I going? (South, every time!)

Watch. *Object #45: Containers from Robert Peary Polar Expedition* (A History of the Navy in 100 Objects, 6:52). <https://www.youtube.com/watch?v=d4yfCrSeN20>

After the story: Look at the real containers from Peary's polar trips, and listen for how much Matthew Henson did on all eight expeditions.

Note: Captions were not available to check; preview it first. The description says Henson got little credit because he was African-American. That is a historical fact, but parents may want to talk it over.

KEY TERMS

North Pole

The point at 90° north latitude where all the lines of longitude meet. It lies in the middle of the Arctic Ocean, on floating sea ice.

sea ice

Frozen ocean water. Arctic sea ice is several feet thick, cracks open and drifts with the wind and currents.

lead

A crack of open water in the sea ice. Leads can stop a sledge party for hours or days.

pressure ridge

A wall of broken ice blocks pushed up where two sheets of sea ice crash together.

support party

A team that carries food and fuel ahead for the main party, breaks the trail, and then turns back.

nautical mile

The sailor's mile, equal to one minute of latitude. One degree of latitude is 60 nautical miles, and one nautical mile is about 1.15 ordinary (statute) miles.

CORE IDEAS

The story. In early April 1909, on the windy sea ice of the Arctic Ocean, six men and their dog teams pushed north as fast as they could go. The leader was Robert E. Peary, an officer of the United States Navy who had spent more than twenty years exploring the Arctic and had tried for the North Pole before. Beside him was Matthew Henson, his right-hand man, and four Inuit hunters from Greenland: Ootah, Egingwah, Seegloo and Ooqueah. On April 6, Peary stopped, took sightings of the sun, and announced that they were at the Pole or very close to it. They planted flags, took photographs and hurried back south. When Peary's news reached the world that September, it set off one of the great arguments in the history of exploration, and it has never fully ended.

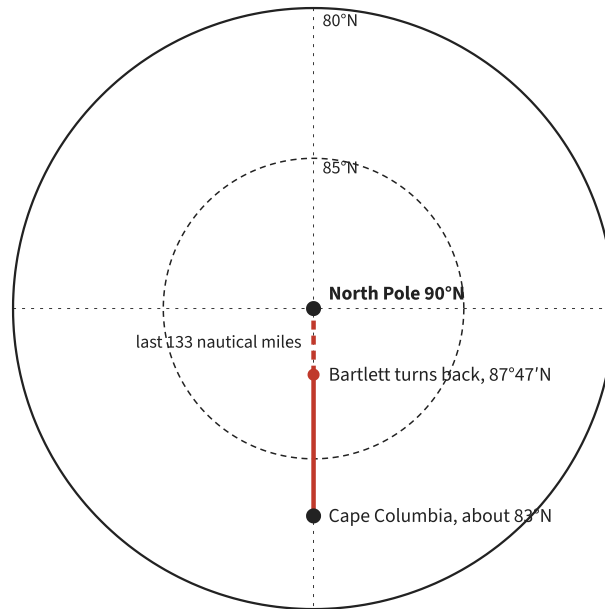
Matthew Henson. Henson was born in Maryland in 1866 and went to sea as a cabin boy when he was about twelve. He met Peary in 1887 and stayed with him for more than twenty years. Henson learned to speak the Inuit language, drive dog teams, build and repair sledges and hunt for food, and the Inuit trusted and liked him. Many who knew the expeditions said he was the most skilled sledge driver in the party. Because Henson was black, America was slow to honor him. For years he worked as a clerk in a New York government office. Honors finally came late in his life, and in 1988 his body was moved to Arlington National Cemetery and buried beside Peary's.

How it worked. Peary's ship, the *Roosevelt*, with Captain Bob Bartlett, pushed north through the ice in 1908 to Cape Sheridan on Ellesmere Island and spent the dark winter there. On March 1, 1909, about two dozen men and more than 130 dogs set out from Cape Columbia, the northern tip of Canada, at about 83°N. Peary used **support parties**. Each team carried food and fuel north, broke the trail and built snow houses, and then turned back, leaving its supplies for those going on. The trail crossed **pressure ridges** of jumbled ice and **leads** of open water. On April 1, Bartlett's party, the last support party, turned back at about 87°47'N. That left about 133 nautical miles to go.

The big idea: was it true? Here is the problem. After Bartlett left, no one with Peary could check his navigation. Henson and the Inuit men were superb travelers, but none of them took sightings. Peary also said that his party covered the last 133 nautical miles in about five days, much faster than they had traveled before. To make it stranger, Dr. Frederick Cook announced just days before Peary that *he* had reached the Pole in 1908. Cook's claim soon fell apart for lack of proof. Peary's claim was accepted by Congress and the National Geographic Society, but doubters never went away. In 1988 the British explorer Wally Herbert, who had reached the Pole on foot himself in 1969, studied Peary's diary and concluded that Peary probably fell short. A study for the National Geographic Society in 1989 argued that Peary did get close. The honest answer is that we cannot be certain. That is why this lesson says *near* the North Pole. A true explorer brings back evidence that others can check.

On the map. The North Pole is not on land. It lies in the middle of the Arctic Ocean, where the water is more than 13,000 feet (about 4,000 m) deep, covered by a crust of sea ice that is always drifting. At the Pole every line of longitude meets, and every direction is south. The

best way to see the Arctic is on a **polar-view map**, drawn as if you were looking down on the top of the globe. The lines of latitude become circles around the Pole, and the lines of longitude become spokes like a wheel. Because each degree of latitude is 60 nautical miles, a traveler can count the distance to the Pole: from Cape Columbia at about 83°N, it is about 7 degrees, or about 420 nautical miles (about 480 miles, or 780 km), in a straight line.



70°W meridian (toward Ellesmere Island)
Rings: 1 degree of latitude = 60 nautical miles

Looking down on the top of the world. Peary's route north from Cape Columbia, and the place where Bartlett turned back.

PICTURE STUDY



The Peary Sledge Party and Flags at the North Pole, Robert E. Peary (photographer), April 6–7, 1909 · Black-and-white photograph · Published in Peary's book *The North Pole* (1910); prints are held in several American collections

Peary took this photograph at the camp he named Camp Jesup, where he believed he had reached the Pole. It shows Matthew Henson and the four Inuit men, Ootah, Egingwah, Seegloo and Ooqueah, standing on a snow ridge with the flags the expedition carried. Peary himself does not appear, because he was behind the camera.

This one picture became the most famous image of the expedition. Years later, people who studied the controversy even measured the shadows in Peary's photographs to try to work out the height of the sun, and so the latitude where they were taken.

Look closely

- Count the people. How many are there, and who is missing from the picture? Why?
- Look at their clothes. What are they made of, and why would furs be better than wool in the Arctic?
- Look at the ground. Is it smooth, or broken and piled up? What would it be like to drive a sledge over it?
- Find the flags. What do you think the men wanted to show the world with them?

Talk about it

1. Can a photograph by itself prove where it was taken? What else would you need?
2. Matthew Henson stands at the center of the picture. Why do you think he received so little credit for many years?

PROJECT: A POLAR-VIEW MAP OF THE ARCTIC

Most maps put the North Pole along the top edge, stretched out into a line. Explorers of the poles needed a different kind of map, one that looks straight down on the top of the globe. You will draw one and plot the route north from Cape Columbia.

You will need

- A large sheet of paper or poster board
- A pencil, string and a thumbtack (to make a compass for circles), or a dinner plate and a saucer
- A ruler and a protractor
- Colored pencils (blue for water and ice, red for the route)
- A globe or a world atlas with a map of the Arctic

Steps

1. Mark a dot in the center of your paper. This is the North Pole, 90°N.
2. Tie the string to the pencil. Pin the other end at the Pole and draw a circle 2 inches out. Label it 85°N. Draw another circle 4 inches out and label it 80°N. Each inch now stands for 2½ degrees, or 150 nautical miles.
3. Use the protractor to draw spokes from the Pole every 30 degrees. Label the spoke pointing straight down 70°W. On a map that looks down on the North Pole, longitude grows eastward as you go counterclockwise, so go counterclockwise from the bottom spoke and label the others 40°W, 10°W, 20°E, 50°E and so on all the way around.
4. Using your globe or atlas, sketch the northern coasts of Greenland, Ellesmere Island and Alaska and Russia as well as you can near the 80°N circle.
5. Mark Cape Columbia at about 83°N on the 70°W spoke (2.8 inches from the Pole). Mark Bartlett's turning point at 87°47'N (about 0.9 inch from the Pole).
6. Draw Peary's route in red from Cape Columbia to the Pole. Draw the last part, after Bartlett turned back, as a dashed line and label it "No navigator could check this part."
7. Add a title, a scale (1 inch = 150 nautical miles) and a small compass note: "At the Pole, every direction is south."

Tips

- Keep your circles light at first; you can ink them when you are happy with them.
- On a north polar map, the 0° meridian through Greenwich, England, points toward Europe. Find it on your globe first, and the other spokes will fall into place.
- You will use this same map again in Lesson 7.2 for the South Pole and in your unit portfolio.

Check your work

- My map has the Pole at the center with latitude circles and longitude spokes.

- I marked Cape Columbia and Bartlett's turning point at the right distance from the Pole.
- I can use my scale to measure how far Peary's party had left to go.

MAP NOTEBOOK

1. Draw a cross-section of the Arctic Ocean at the Pole: a thin layer of sea ice on top, a pressure ridge, a lead of open water, and the deep ocean underneath. Label the water depth: more than 13,000 feet.
2. Make a two-column chart titled "Did Peary Reach the Pole?" List the evidence for his claim on one side and the reasons for doubt on the other.
3. Sketch Matthew Henson driving a dog team, and write three skills he brought to the expedition.

From history. Peary's Arctic years also included a real wrong. In 1897 he brought six Inuit people from Greenland to New York on his ship, along with a huge iron meteorite from Cape York that he later sold to the American Museum of Natural History. Within months, four of the six Inuit had died of illness. One of the survivors, a boy named Minik, was left in New York far from his people and spent years trying to get home. Brave explorers can still do great harm when they treat other people as specimens, and Peary's story should be told with both his endurance and this wrong in view.

WORKED EXAMPLES

Example 1. Cape Columbia lies at about 83°N . How far is it, in a straight line, to the North Pole? Give the answer in nautical miles and in ordinary miles.

(Use the map or drawing "From 83°N to 90°N is 7 degrees of latitude." shown earlier in this lesson.)

1. The Pole is at 90°N . Subtract: $90^{\circ} - 83^{\circ} = 7^{\circ}$.
2. Each degree of latitude is 60 nautical miles: $7 \times 60 = 420$ nautical miles.
3. One nautical mile is about 1.15 ordinary miles: $420 \times 1.15 = 483$ miles.

Answer: About 420 nautical miles, or about 480 miles (about 780 km). The real trail was much longer because of ridges, leads and drifting ice.

Example 2. Peary's party left Cape Columbia on March 1, 1909. Bartlett turned back on April 1 at $87^{\circ}47'N$, about 280 nautical miles from Cape Columbia. Peary said the party then covered the last 133 nautical miles to the Pole in about 5 days. Compare the average speed of the two parts of the trip.

1. March 1 to April 1 is 31 days. First part: $280 \div 31 \approx 9$ nautical miles a day.
2. Last part: $133 \div 5 \approx 27$ nautical miles a day.
3. Compare: $27 \div 9 = 3$. The claimed speed on the last part was about three times the speed before.

Answer: About 9 nautical miles a day before Bartlett turned back, and about 27 a day afterward: three times as fast. This sudden jump is one of the main reasons people doubt Peary's claim. His defenders answer that the main party had been saving its strength and its best dogs for the final dash.

PRACTICE

1. **EASY** Name the six men in the party that Peary said reached the North Pole on April 6, 1909.
2. **EASY** Is the North Pole on land or on the ocean? What covers it?
3. **EASY** You are standing exactly at the North Pole. In which direction must you walk to reach Canada? To reach Russia?
4. **MEDIUM** Bartlett turned back at $87^{\circ}47'N$. How many degrees and minutes was that from the Pole? How many nautical miles?
5. **MEDIUM** A polar map uses $1 \text{ inch} = 150 \text{ nautical miles}$. How many inches from the Pole should you draw the $85^{\circ}N$ circle? The $80^{\circ}N$ circle?
6. **MEDIUM** Why did Peary use support parties instead of sending only one small team from the start?
7. **HARD** The sea ice drifts. Suppose your camp drifts 4 nautical miles south while you sleep, and you then travel 15 nautical miles north. How much closer to the Pole are you than when you went to sleep?
8. **CHALLENGE** In a short paragraph, explain why we say Peary and Henson reached "near" the North Pole, and what kind of evidence would have settled the question.

COMMON MISTAKES

- Thinking the North Pole is on a continent like the South Pole. It is on floating sea ice over a deep ocean.
- Thinking a flag and a photograph prove where you were. Proof of position comes from careful sightings that someone else can check.
- Forgetting Matthew Henson and the four Inuit men. Peary could not have traveled the Arctic without their skill.

Make it a game · Sledge to the Pole. Draw a ladder of 7 rungs on paper, labeled 83°N at the bottom up to 90°N at the top. Each player rolls a die on their turn: 1 means a lead of open water (stay put), 2 means a pressure ridge (move back one rung if you are not at the bottom), and 3 to 6 means good ice (move up one rung). Before each move, the player must say how many nautical miles are left to the Pole (60 for each rung left). The first to reach 90°N must then answer one question about the evidence for the claim to win.

Scripture. “He that is first in his own cause seemeth just; but his neighbour cometh and searcheth him.” (Proverbs 18:17, KJV)

A claim can sound convincing until someone checks it. Peary and Cook both told their own stories first; careful searching by others is how the truth comes out. Good explorers, and good students, welcome having their work checked.

Practice answers

1. Robert Peary, Matthew Henson, Ootah, Egingwah, Seegloo and Ooqueah.
2. It is on the ocean, the Arctic Ocean, covered by a crust of drifting sea ice.
3. South, both times. At the North Pole every direction is south.
4. $90^{\circ}00' - 87^{\circ}47' = 2^{\circ}13'$. That is $2 \times 60 + 13 = 133$ nautical miles.
5. 85°N is $5^{\circ} \times 60 = 300$ nautical miles away, so 2 inches. 80°N is $10^{\circ} \times 60 = 600$ nautical miles away, so 4 inches.
6. One small team could not carry enough food and fuel for the whole trip. Support parties carried supplies forward, broke the trail and built snow houses, then turned back, so the final party could start its dash fresh and fully loaded.
7. $15 - 4 = 11$ nautical miles closer. Drifting ice is one reason travel on the Arctic Ocean is so hard and why careful sightings matter.
8. Sample answer: After Bartlett turned back, no one who could check Peary's navigation went with him, and the speeds he claimed for the last 133 nautical miles were much faster than before. Some experts think he reached the Pole and others think he fell short, so we cannot be sure. A second trained navigator taking his own sightings, or careful records that others could check right away, would have settled it.

7.2 AMUNDSEN REACHES THE SOUTH POLE

OBJECTIVES

- Tell how Roald Amundsen and four Norwegian companions reached the South Pole on December 14, 1911, and how Robert Falcon Scott's party arrived after them.
- Explain how dogs, skis, fur clothing and food depots helped Amundsen succeed, and compare Antarctica, a high, ice-covered continent, with the Arctic Ocean.
- Use latitude to find distances in nautical miles and test which glove insulates best.

Warm-up. Hold an ice cube in your bare hand for as long as is comfortable (not more than a minute), then put it in a bowl. Now put on a mitten or glove and hold a new ice cube. What changed? Which felt colder, and why? Keep your thinking; you will test it properly in this lesson's project.

Watch. *14th December 1911: Norwegian explorer Roald Amundsen becomes the first to reach the South Pole* (HistoryPod, 2:21). <https://www.youtube.com/watch?v=BHTB92tmvyU>

After the story: Follow Amundsen from Norway to Framheim on the Bay of Whales, and watch for his depots across the Ross Ice Shelf before the final push to the Pole on December 14, 1911.

Note: Captions were not available to check; preview it first. It mentions that Scott and his team died on their way back from the Pole. The video calls the American claim to the North Pole 'now-disputed', but the previous lesson presents Peary and Henson reaching it in 1909.

Backup video. *14th December 1911: Roald Amundsen reaches the South Pole* (HistoryPod, 2:32). <https://www.youtube.com/watch?v=aOuFEX1F1qA>

As review: Retrace Amundsen's secret change of plan, his base at Framheim, and how his team reached the Pole five weeks before Scott. Note: Captions were not available to check; preview it first. This is an older version of the main video from the same channel and also mentions that Scott's team died. The video calls the American claim to the North Pole 'now-disputed', but the previous lesson presents Peary and Henson reaching it in 1909.

KEY TERMS

South Pole

The point at 90° south latitude. It lies on the ice sheet of Antarctica, about 9,300 feet (2,800 m) above sea level.

ice shelf

A huge, thick sheet of ice that flows off the land and floats on the sea. Amundsen built his base on the Ross Ice Shelf.

depot

A store of food and fuel left along a route ahead of time, to be picked up on the way.

polar plateau

The high, flat, very cold ice sheet in the middle of Antarctica, on which the South Pole stands.

insulation

A material that slows the flow of heat, such as fur, wool or trapped air.

CORE IDEAS

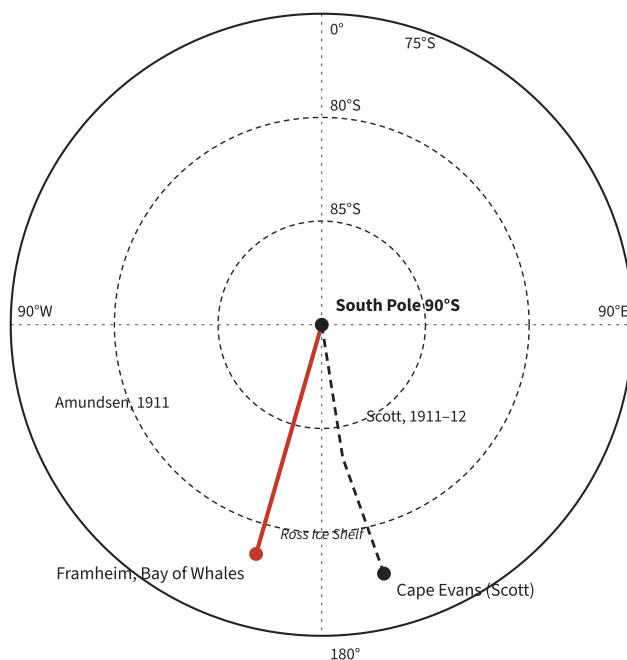
The story. On December 14, 1911, five Norwegians on skis, with their sledges and dog teams, stopped on a flat white plain at the bottom of the world. Their leader, Roald Amundsen, had counted every mile. The men were Olav Bjaaland, Helmer Hanssen, Sverre Hassel, Oscar Wisting and Amundsen himself. Together they gripped a Norwegian flag and planted it at the South Pole. For the next few days they took careful sightings of the sun and sent men skiing out in different directions to be sure they had truly reached the spot. Before they left, they put up a small tent, which they called Polheim, and left a letter inside for the British explorer Robert Falcon Scott, who they knew was also on his way.

A race no one expected. Amundsen had planned to drift across the Arctic Ocean in his ship, the *Fram*. When he heard in 1909 that Peary and Cook both claimed the North Pole, he quietly turned his plan upside down and decided to go south instead. He told his crew only after they had sailed, and he sent Scott a short telegram saying that the *Fram* was heading for the Antarctic. In January 1911 Amundsen set up his base, Framheim, at the Bay of Whales on the edge of the Ross Ice Shelf, at about 78°30'S. That was about 60 miles (50 nautical miles) closer to the Pole than Scott's base on Ross Island.

How it worked. Amundsen won by planning. As a young man he had sailed through the Northwest Passage (1903–1906) and spent two winters near the Netsilik Inuit, learning how they traveled with dogs and dressed in loose fur clothing. Norwegians grow up on skis, and Bjaaland was a champion skier. In February and March 1911, the southern autumn, his men laid **depots** of food at 80°, 81° and 82°S, and marked them with lines of flags stretching out to each side so they could not be missed in a snowstorm. On October 19 the polar party left Framheim with four sledges and 52 dogs. They climbed a steep, broken glacier, which Amundsen named the Axel Heiberg Glacier, up to the **polar plateau**. There they did a hard thing they had planned from the start: they killed many of the dogs to feed the other dogs and themselves. Amundsen named the camp the Butcher's Shop. It was grim, but it was the plan that brought every man home.

The other party. Scott chose a different way. He brought ponies and motor sledges, which both failed in the cold, and his men hauled their own sledges much of the way. Scott, Edward Wilson, Henry Bowers, Lawrence Oates and Edgar Evans reached the Pole on January 17, 1912, and found Amundsen's tent waiting. All five died on the way back. Scott's last diary, found the next November, tells of great courage. Amundsen's party returned to Framheim safe and well on January 25, 1912. Amundsen later wrote that victory comes to the one who has everything in order, and that people call this luck.

On the map. The two poles are opposites. The North Pole lies on a frozen ocean near sea level. The South Pole lies on a **continent**, Antarctica, buried under an ice sheet so thick that the Pole stands about 9,300 feet (2,800 m) high. Because the South Pole is high and far from the warming ocean, it is much colder than the North Pole. On a **polar-view map** of the south, the Pole is in the center, the latitude lines are rings, and Amundsen's route runs almost straight up a single spoke of longitude from the Bay of Whales.



Looking down on the bottom of the world: Amundsen's route (red) and Scott's route (dashed).

PICTURE STUDY



Amundsen's Party at the South Pole, Olav Bjaaland (photographer), December 17, 1911 · Black-and-white photograph · National Library of Norway, Oslo

Olav Bjaaland, the champion skier of the party, carried a small camera to the Pole. This photograph shows Amundsen, Helmer Hanssen, Sverre Hassel and Oscar Wisting beside Polheim, the little tent they left at the Pole with a Norwegian flag flying above it. Bjaaland is missing from the picture because he was taking it.

Look closely

- Look at the land around the tent. Is there any hill, rock or tree? What does that tell you about the polar plateau?
- Look at the men's faces and posture. Where are they looking?
- Find the flag. Why did the men leave a tent and a flag behind instead of taking everything home?
- Compare this photograph with Peary's photograph in Lesson 7.1. What is alike? What is different about the ground?

Talk about it

1. When Scott's party arrived a month later, they found this same tent. How do you think they felt?
2. Amundsen also left a letter in the tent for Scott. Why might he have done that?

PROJECT: THE GLOVE TEST: WHICH KEEPS AN ICE CUBE LONGEST?

Amundsen's men wore loose fur clothing like the Inuit, while many British explorers relied on wool and windproof cloth. Which materials keep cold out (or heat in) best? You will run a

fair test with real gloves and ice cubes and record your results like a scientist.

You will need

- 4 or 5 different gloves or mittens (for example a thin cotton glove, a knit wool mitten, a fleece glove, a leather glove, a ski glove)
- Ice cubes all the same size, from the same tray
- Small plastic sandwich bags
- A bare ice cube in a bag on a plate (the control)
- A clock or timer
- A notebook, pencil and ruler for a results table

Steps

1. Write your prediction: which glove will keep its ice cube frozen longest? Why?
2. Put one ice cube in each sandwich bag and seal it so the gloves stay dry.
3. Slide one bagged cube into the palm of each glove. Lay the gloves side by side on a table, away from sunshine and heaters. Put the bare bagged cube on a plate next to them.
4. Start the timer. Every 15 minutes, quickly peek into each glove and write down whether the cube is whole, half melted or all melted.
5. Record the time when each cube has completely melted.
6. Make a bar graph with one bar for each glove, showing minutes until melted.
7. Write two sentences: Which glove insulated best? What does it have that the others do not (thickness, trapped air, a windproof layer)?

Tips

- A fair test changes only one thing. Every cube must be the same size and every glove must sit in the same place.
- Insulation works both ways: a good glove keeps cold in the ice cube in this test, and keeps warmth in your hand outdoors.
- Thick, fluffy materials trap air, and still air is a poor carrier of heat. That is why fur works so well.

Check your work

- I made a prediction and a fair test with a control.
- I recorded times in a table and drew a bar graph.
- I can explain why the best glove insulated best.

MAP NOTEBOOK

1. Add the South Pole to your polar maps: draw a second polar-view map with the South Pole at the center and rings for 80°S and 85°S. Mark Framheim at about 78°30'S and draw Amundsen's route.

2. Draw a side view (profile) of Amundsen's route: flat ice shelf near sea level, the steep Axel Heiberg Glacier, then the high polar plateau at about 9,300 feet at the Pole.
3. Make a chart comparing Amundsen and Scott: how they traveled, what they wore, what they ate, and how the journey ended.

From history. Amundsen went on to fly over the North Pole in the airship *Norge* on May 12, 1926, with the American Lincoln Ellsworth and the Italian Umberto Nobile. Because Peary's claim and a 1926 airplane claim are both doubted, many historians say that Amundsen and his old companion Oscar Wisting, who was also aboard, were the first people certainly to have seen both poles. Amundsen died in 1928 when his plane was lost in the Arctic while he was searching for Nobile after another airship crash.

WORKED EXAMPLES

Example 1. Framheim lay at about $78^{\circ}30'S$. How far was it in a straight line to the South Pole? Amundsen left on October 19 and reached the Pole on December 14. What was his average straight-line progress per day?

(Use the map or drawing "From Framheim to the Pole is $11\frac{1}{2}$ degrees of latitude." shown earlier in this lesson.)

1. Subtract: $90^{\circ}00' - 78^{\circ}30' = 11^{\circ}30'$.
2. Change to nautical miles: $11 \times 60 = 660$, plus 30 = 690 nautical miles.
3. Count the days: October 19 to October 31 is 12 days, November has 30, and December 1 to 14 is 14 more: $12 + 30 + 14 = 56$ days.
4. Divide: $690 \div 56 \approx 12.3$ nautical miles a day.

Answer: About 690 nautical miles (about 790 miles, or 1,280 km), at an average of about 12 nautical miles a day in a straight line. The real route was longer, with rest days and the hard glacier climb.

Example 2. Amundsen reached the South Pole on December 14, 1911. Scott reached it on January 17, 1912. How many days later did Scott arrive?

1. Count the rest of December after the 14th: $31 - 14 = 17$ days.
2. Add the days in January up to the 17th: 17 days.
3. Total: $17 + 17 = 34$ days.

Answer: 34 days, almost five weeks later.

PRACTICE

1. **EASY** Name the five men who reached the South Pole with Amundsen's party (include Amundsen).

2. **EASY** What is under the South Pole: ocean or land? What is under the North Pole?
3. **EASY** What is a depot, and why did Amundsen mark his depots with lines of flags out to each side?
4. **MEDIUM** Amundsen's depots were at 80°S, 81°S and 82°S. How many nautical miles from Framheim (78°30'S) was each one?
5. **MEDIUM** Change 690 nautical miles to ordinary miles, using 1 nautical mile $\approx$ 1.15 miles.
6. **MEDIUM** Give two reasons the South Pole is much colder than the North Pole.
7. **HARD** Suppose a dog team travels 15 nautical miles a day. How many days would it take to go from the 82°S depot to the Pole, with no rest days?
8. **CHALLENGE** In a short paragraph, explain why Amundsen's party came home safely while Scott's party did not. Use at least two of these words: dogs, skis, depots, furs, planning.

COMMON MISTAKES

- Thinking the South Pole is on sea ice like the North Pole. It is on a high ice sheet over land.
- Saying Amundsen was just lucky. He planned for years and learned from the Inuit; he himself said good preparation is what people call luck.
- Forgetting that a degree of latitude is 60 nautical miles, not 60 ordinary miles. One nautical mile is about 1.15 ordinary miles.

Make it a game • Depot Dash. Hide three “depots” (small cards marked 80°S, 81°S and 82°S) in a room or yard, each with a line of three or four paper flags stretched out to the sides. Blindfold or turn the player around, then have them walk toward each depot in turn while a partner calls out only “warmer” or “colder.” Time each run. Then remove the side flags and play again. Which version is easier, and why did Amundsen use flags out to the sides?

Scripture. “The thoughts of the diligent tend only to plenteousness; but of every one that is hasty only to want.” (Proverbs 21:5, KJV)

Amundsen's careful thought about dogs, skis, food and depots brought five men home in good health. Diligence is not the same as being in a hurry; it means doing the hard work of planning before the hard work of the journey.

Practice answers

1. Roald Amundsen, Olav Bjaaland, Helmer Hanssen, Sverre Hassel and Oscar Wisting.
2. The South Pole is on land, the continent of Antarctica, under a thick ice sheet. The North Pole is on the Arctic Ocean, covered with sea ice.
3. A depot is a store of food and fuel left ahead of time along the route. The lines of flags made a wide target, so the men could find the depot even if they were a little off course or the weather was bad.
4. 80°S: $1^{\circ}30' = 90$ nautical miles. 81°S: $2^{\circ}30' = 150$ nautical miles. 82°S: $3^{\circ}30' = 210$ nautical miles.

5. $690 \times 1.15 = 793.5$, or about 790 miles.
6. It is very high, about 9,300 feet up on the ice sheet, and air is colder at height. It is on a continent far from the ocean, while the North Pole sits on an ocean whose water under the ice gives off some warmth.
7. From 82°S to 90°S is $8^{\circ} \times 60 = 480$ nautical miles. $480 \div 15 = 32$ days.
8. Sample answer: Amundsen planned every detail. His men were expert skiers and dog drivers, and they wore loose fur clothing learned from the Inuit. Dogs pulled the sledges faster than men could, and the plan to feed some dogs to the others meant less food had to be carried. Well-marked depots supplied them on the way home. Scott's ponies and motor sledges failed, his men hauled their own heavy sledges, and they ran short of food and fuel in terrible weather on the return.

7.3 SHACKLETON'S ENDURANCE

OBJECTIVES

- Tell the story of the *Endurance* from 1914 to 1916: the ship trapped and crushed in the Weddell Sea, the boat journeys and the rescue of every man of her crew.
- Trace the drift of the ice and the voyage of the *James Caird* on a latitude and longitude map, and find distances and times.
- Explain how leadership, seamanship and a sextant brought the crew through, and name honestly what went wrong.

Warm-up. Float a small toy boat or a bottle cap in a sink or tub. Crowd ice cubes tightly around it, then gently push the ice from two sides with your hands. What happens to the boat? Now imagine the ice is a mile wide and several feet thick, and the push comes from the wind across a whole sea.

Watch. *Sir Ernest Shackleton's account of the Imperial Trans-Antarctic Expedition on Endurance* (UK Antarctic Heritage Trust, 3:30). <https://www.youtube.com/watch?v=Fu5UTO1qN-I>

After the story: Hear Shackleton's own account of the *Endurance* trapped in the Weddell Sea pack ice, and picture the men waiting through the long Antarctic winter.

Note: Captions were not available to check; preview it first. The video comes from the UK Antarctic Heritage Trust and may use British spellings and terms.

KEY TERMS

pack ice

Sea ice broken into floes that crowd together and drift with the wind and currents.

beset

Trapped in the ice and unable to move, as a ship can be when the pack closes around it.

floe

A single flat piece of floating sea ice, from a few yards to miles across.

sextant

A navigator's instrument for measuring the angle of the sun or a star above the horizon, used to find latitude and, with an accurate clock, longitude.

drift

Movement caused by wind and current rather than by sails or engines.

CORE IDEAS

The story. In December 1914 the ship *Endurance* sailed from the whaling station on South Georgia island into the Weddell Sea, with 28 men under Sir Ernest Shackleton. Shackleton's plan was bold: land on the coast of Antarctica and cross the whole continent on foot by way

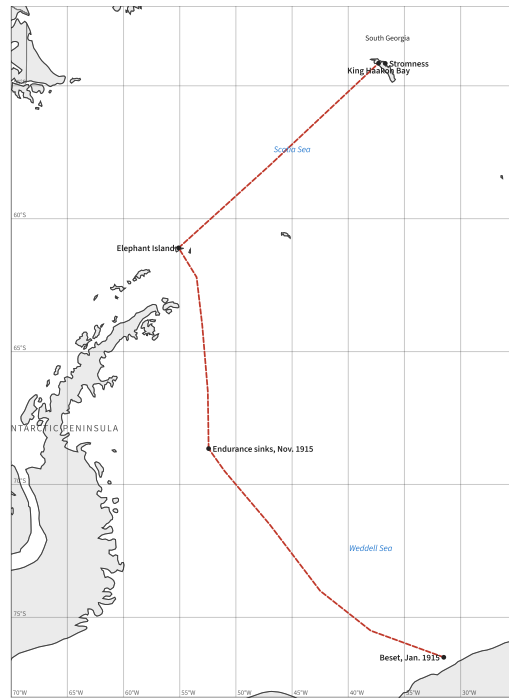
of the South Pole. In January 1915, almost within sight of land, the pack ice closed around the ship. The *Endurance* was **beset**. Through the long dark winter she drifted with the ice, and as spring came the floes squeezed her until her timbers cracked. On October 27, 1915, Shackleton ordered the men onto the ice. On November 21 the ship slipped beneath it. Shackleton told his men that the new goal was simple: to bring every one of them home alive.

How they survived. For months the men camped on drifting floes, living on seals, penguins and the stores they had saved. The ice drifted slowly north. In April 1916, as the floes broke up, they launched three small boats and after a week of freezing, sleepless sailing reached Elephant Island, a rocky, storm-beaten place off the tip of the Antarctic Peninsula. It was the first land they had stood on in about sixteen months. No one would ever look for them there. So on April 24, Shackleton and five others, Frank Worsley, Tom Crean, Harry McNish, John Vincent and Timothy McCarthy, set out in the 22-foot boat *James Caird* for South Georgia, about 800 nautical miles away across the stormiest ocean on earth.

How they found their way. Worsley, the captain of the *Endurance*, navigated with a **sextant** and a chronometer, the same tools you studied in Units 2 and 3. In sixteen days the clouds broke only a few times, and Worsley had to brace himself in the pitching boat, with men holding him, to catch the sun for a moment. If he missed South Georgia, the next land downwind was thousands of miles away. On May 10, 1916, they landed at King Haakon Bay, on the wrong side of the island from the whaling stations. Shackleton, Worsley and Crean then crossed the unmapped mountains and glaciers of South Georgia in about 36 hours, with a rope, a carpenter's adze and screws in their boots for grip, and walked into Stromness whaling station on May 20.

Every man saved. The 22 men left on Elephant Island under Frank Wild lived under two upturned boats. Shackleton tried three times to reach them in ships, and the ice turned him back each time. On August 30, 1916, on the fourth try, the small Chilean steamer *Yelcho*, commanded by Luis Pardo, came through, and every man was alive. The story was not perfect. On the far side of Antarctica a second team, the Ross Sea party, had been laying depots for the crossing, and three of its men died before they were rescued in January 1917. And some of the *Endurance* men, including the carpenter McNish who had once refused orders on the ice, were later left out of the Polar Medal awards, which many think was unfair.

On the map. The Weddell Sea lies in a great bay of Antarctica, east of the Antarctic Peninsula. Winds and currents turn slowly around it in a clockwise circle and push the pack ice north along the peninsula. That is the path the *Endurance* drifted, from about 76°S to where she sank at about 68°39'S, 52°26'W. In March 2022 explorers using an underwater robot found the wreck about 10,000 feet (3,000 m) down, only about four miles from the position Worsley had written down, a fine tribute to his careful navigation.



The drift of the Endurance, the boat journey to Elephant Island and the voyage of the James Caird (routes approximate).

PICTURE STUDY



The Endurance at Night, Frank Hurley, August 27, 1915 · Photograph from a glass-plate negative, lit by flash powder · Collections include the State Library of New South Wales, Sydney, the Royal Geographical Society, London, and the Scott Polar Research Institute, Cambridge

Frank Hurley was the Australian photographer of the expedition. During the dark Antarctic winter of 1915, he set up his camera on the ice and fired many flashes of magnesium powder from different places around the ship, one after another, while the camera's shutter stayed

open. The result is one of the most famous photographs of exploration: the *Endurance* shining white with frost, as if made of glass.

When the ship was crushed, Hurley went back into the wreck to rescue his glass-plate negatives. Shackleton let him keep only about 150 of them, because every pound had to be carried, and Hurley broke the rest so he would not be tempted to go back for them. That is why we can still see the *Endurance* today.

Look closely

- Find the masts and the rigging. Why do they look white?
- Look at the ice around the ship. Is it smooth or rough? Can you see where the ship is stuck?
- Where is the light coming from? How is this different from an ordinary daytime photograph?
- Find anything that shows the size of the ship compared with the ice.

Talk about it

1. Why do you think Hurley worked so hard, in such cold, to make this picture?
2. If you could save only a few of your photographs from a shipwreck, how would you choose?

PROJECT: PLOT THE ENDURANCE STORY ON A GRID MAP

Worsley kept the position of the ship and the camps in latitude and longitude, day after day. You will turn real positions into a map, just as he did, and measure the distances the men traveled by drift, by boat and on foot.

You will need

- A sheet of graph paper
- A ruler and a pencil
- Colored pencils (blue for the drift, red for the boats, green for the walk across South Georgia)
- An atlas map of Antarctica and the South Atlantic for reference

Steps

1. Draw a grid. Label the lines across from 52°S at the top to 78°S at the bottom, every 2 degrees. Label the lines up and down from 60°W on the left to 30°W on the right, every 5 degrees. Remember: in the Southern Hemisphere, latitude numbers grow as you go down the page toward the Pole.
2. Plot these points and label them: Beset, January 1915 (about 76°30'S, 31°30'W); *Endurance* sinks, November 1915 (about 68°39'S, 52°26'W); Elephant Island (about 61°S, 55°W); King Haakon Bay, South Georgia (about 54°S, 37°W).

3. Connect Beset to Endurance sinks with a wavy blue line, and add an arrow showing the drift went north and west.
4. Draw a red line from Endurance sinks north to Elephant Island for the camps on the ice and the boat journey.
5. Draw a bold red line from Elephant Island to King Haakon Bay and label it “James Caird, April 24 – May 10, 1916.”
6. Using the rule that one degree of latitude is 60 nautical miles, work out how far north the ship drifted between being beset and sinking.
7. Add a title, a compass rose and a key.

Tips

- Southern latitudes and western longitudes can be confusing. Say them aloud: “sixty-one degrees south, fifty-five degrees west.”
- Only distances straight north and south can be found by counting degrees of latitude. East-west degrees get shorter as you go toward the poles.

Check your work

- My grid is labeled with south latitudes and west longitudes in the right order.
- I plotted all four points correctly.
- I found the north-south drift distance in nautical miles.

MAP NOTEBOOK

1. Draw the *James Caird*: a 22-foot open boat with a makeshift deck of canvas and sledge runners, and six men aboard. Label the sail, the deck and where the men slept.
2. Draw Worsley taking a sun sight with a sextant while two men hold him steady in the pitching boat.
3. Make a timeline from August 1914 to January 1917 with at least seven events from the story.

From history. Years later, in his book *South* (1919), Shackleton wrote that during the long march across South Georgia it often seemed to him that there were four men walking, not three. Worsley and Crean said they had felt the same. Shackleton believed Providence had guided them, and he wrote that he could not tell the whole story of those days without speaking of it.

WORKED EXAMPLES

Example 1. The *James Caird* sailed about 800 nautical miles from Elephant Island (left April 24, 1916) to South Georgia (landed May 10, 1916). How many days did it take, and what was the average distance per day? Give the total distance in ordinary miles too.

(Use the map or drawing “The voyage of the *James Caird*.” shown earlier in this lesson.)

1. Days: from April 24 to April 30 is 6 days, plus 10 days in May: $6 + 10 = 16$ days.
2. Average: $800 \div 16 = 50$ nautical miles a day.
3. Ordinary miles: $800 \times 1.15 = 920$ miles.

Answer: 16 days, about 50 nautical miles a day; the whole voyage was about 920 miles (about 1,480 km).

Example 2. The 22 men left on Elephant Island landed there on April 15, 1916, and were rescued on August 30, 1916. How many days did they spend on the island?

1. April: from the 15th to the 30th is $30 - 15 = 15$ days.
2. May 31 + June 30 + July 31 = 92 days.
3. August: 30 days.
4. Total: $15 + 92 + 30 = 137$ days.

Answer: 137 days, about four and a half months.

PRACTICE

1. **EASY** What was Shackleton’s original plan for the expedition?
2. **EASY** What happened to the *Endurance*, and what did Shackleton say the new goal was?
3. **EASY** Name the three men who crossed the mountains of South Georgia to reach the whaling station at Stromness.
4. **MEDIUM** The ship was beset at about $76^{\circ}30'S$ and sank at about $68^{\circ}39'S$. How far north did she drift, in degrees and minutes and in nautical miles?
5. **MEDIUM** Elephant Island is at about $61^{\circ}S$ and King Haakon Bay at about $54^{\circ}S$. Is South Georgia north or south of Elephant Island, and by how many degrees of latitude? Why was the boat’s real path longer than this?
6. **MEDIUM** Why did Worsley’s sextant sights matter so much on the *James Caird*?
7. **HARD** The wreck of the *Endurance* was found in 2022 about 3,000 m down. Using $1 \text{ m} \approx 3.3$ feet, about how many feet is that? How many miles deep, to the nearest whole mile ($1 \text{ mile} = 5,280$ feet)?
8. **CHALLENGE** In a short paragraph, explain why we can say every man of the *Endurance* was saved, but also why the expedition was not a complete success.

COMMON MISTAKES

- Saying the whole expedition lost no one. Every man of the *Endurance* was saved, but three men of the Ross Sea party died.
- Repeating the famous newspaper advertisement that begins “Men wanted for hazardous journey.” No copy of it has ever been found, and historians think it was made up later.
- Reading southern latitudes upside down on a grid. In the Southern Hemisphere, the numbers grow larger as you go south toward the Pole.

Make it a game • Find South Georgia. Place a small cup (South Georgia) at one end of a long hallway or yard. The navigator stands at the other end with eyes closed. Three times during the walk, the navigator may open their eyes for just two seconds (a “sun sight”) to adjust course. Partners may give gentle nudges to the side as “storm waves.” Score a point if the navigator stops within one step of the cup. Then try with only one sun sight. How did Worsley feel with so few?

Scripture. “If I take the wings of the morning, and dwell in the uttermost parts of the sea; Even there shall thy hand lead me, and thy right hand shall hold me.” (Psalm 139:9–10, KJV)

The Weddell Sea and Elephant Island are about as far as a person can go into “the uttermost parts of the sea.” Even there, God is present. Shackleton himself felt that he and his men were led and held.

Practice answers

1. To land on the Weddell Sea coast of Antarctica and cross the whole continent on foot by way of the South Pole.
2. She was trapped in the pack ice of the Weddell Sea, drifted for months, was crushed and sank in November 1915. The new goal was to bring every man home alive.
3. Ernest Shackleton, Frank Worsley and Tom Crean.
4. $76^{\circ}30' - 68^{\circ}39' = 7^{\circ}51'$. That is $7 \times 60 + 51 = 471$ nautical miles north (the real drift path was longer because it wandered).
5. South Georgia is north, by about 7 degrees (about 420 nautical miles). The real path was longer because South Georgia is also far to the east, so the boat sailed northeast, and storms pushed it off a straight line.
6. South Georgia is a small island in a vast ocean. If they missed it, the winds and currents would carry them away from any land. The sun sights told Worsley their latitude and longitude so he could steer for the island.
7. $3,000 \times 3.3 = 9,900$ feet, about 10,000 feet. $9,900 \div 5,280 \approx 1.9$, so about 2 miles down.
8. Sample answer: All 28 men of the *Endurance* came home alive after the ship sank, thanks to Shackleton’s leadership, Worsley’s navigation, the courage of the boat crews and the rescue by the *Yelcho*. But the expedition never crossed Antarctica, its ship was lost, and on the other side of the continent three men of the Ross Sea party died.

7.4 HILLARY AND TENZING ON EVEREST

OBJECTIVES

- Tell how Edmund Hillary and Tenzing Norgay reached the summit of Mount Everest on May 29, 1953, as part of John Hunt's British expedition.
- Explain why high mountains are cold and short of air, and read an elevation profile of the climbing route.
- Locate Everest on a map of the Himalaya and compute differences in elevation and rates of climbing.

Warm-up. Take a deep breath and count how many times you can say “Everest” before you need another. Now run in place for one minute and try again. Climbers near the top of Everest feel like that all the time, even when standing still, because each breath holds only about one-third as much oxygen as at sea level. Talk about why that might be.

Watch. *29th May 1953: Edmund Hillary and Tenzing Norgay conquer Mount Everest* (HistoryPod, 2:43). <https://www.youtube.com/watch?v=zvOXn5mKNEE>

After the story: Watch for the moment on May 29, 1953 when Edmund Hillary and Tenzing Norgay reach the summit of Everest, and for the part John Hunt's British expedition played.

Note: Captions were not available to check; preview it first. The video is HistoryPod's '29th May 1953: Edmund Hillary and Tenzing Norgay conquer Mount Everest'; its length and whether it can be embedded were not checked.

KEY TERMS

summit

The highest point of a mountain.

elevation

Height above sea level. Everest's summit is at about 29,032 feet (8,849 m).

Sherpa

A people of the high valleys of eastern Nepal, near Everest, famous for their strength and skill as mountain guides and porters.

col

A low pass or saddle on a ridge between two peaks. The South Col lies between Everest and its neighbor Lhotse.

elevation profile

A side-view drawing of a route that shows how high the ground is along the way.

monsoon

The rainy season wind of South Asia. On Everest it brings heavy snow, so climbers aim for the calmer weeks of May before it arrives.

CORE IDEAS

The story. At about 11:30 in the morning on May 29, 1953, two men in oxygen masks cut the last steps in a ridge of snow and stood on the highest point on earth. One was Edmund Hillary, a tall beekeeper from New Zealand. The other was Tenzing Norgay, a Sherpa climber who lived in Darjeeling, India, and had already been high on Everest more times than almost anyone alive. They shook hands, and then Tenzing threw his arms around Hillary. They stayed about fifteen minutes. Hillary took a photograph of Tenzing holding up his ice axe with its flags. Tenzing, a Buddhist, pressed a few sweets and biscuits into the snow as an offering, and Hillary left a small crucifix that the expedition leader, John Hunt, had given him. Then they started down.

How it was measured. A century earlier, the Great Trigonometrical Survey of India had measured the peaks of the Himalaya from stations on the plains of India, more than 100 miles away, using careful angles and triangles. Mathematicians of the Survey, including Radhanath Sikdar, worked through the numbers and found that the mountain they called Peak XV was the highest of all. In 1856 it was announced at 29,002 feet and later named for Sir George Everest, a former head of the Survey. The Tibetans call it Chomolungma and the Nepalis call it Sagarmatha. In 2020 surveyors from Nepal and China measured it again at 29,032 feet (8,849 m), about 5½ miles straight up.

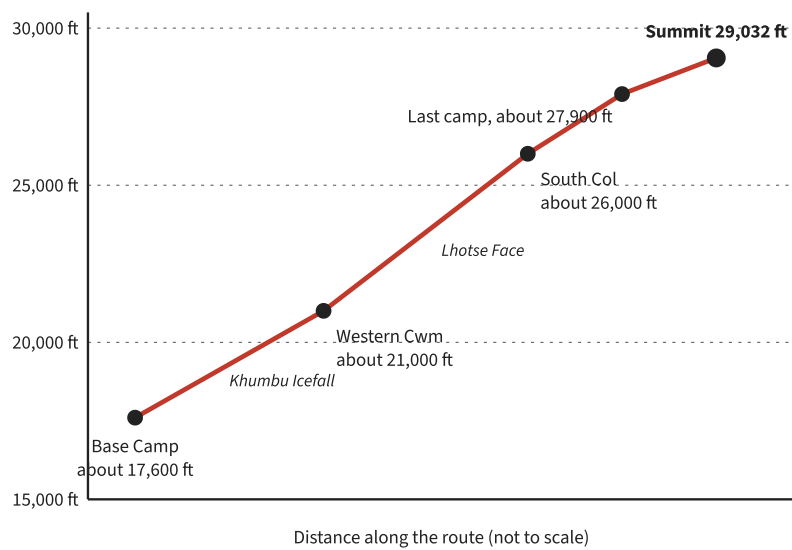
How they climbed it. Many had tried before. George Mallory and Andrew Irvine vanished high on the Tibetan side in 1924, and in 1952 Tenzing and the Swiss climber Raymond Lambert came within about 800 feet. In 1953 Hunt's expedition, with hundreds of porters and a skilled team of Sherpas, carried tons of food, tents and oxygen bottles up from Nepal. They forced a route through the dangerous Khumbu Icefall, up the long valley of snow called the Western Cwm, up the steep Lhotse Face and onto the wind-blasted South Col at about 26,000 feet. On May 26, Tom Bourdillon and Charles Evans reached the South Summit but had to turn back. Then Hillary and Tenzing, helped by a support team, pitched a tiny tent at about 27,900 feet. At 6:30 the next morning they set out, climbed a steep 40-foot step of rock and ice by wriggling up a crack, and reached the top.

The big idea: the roof of the world. The Himalaya rise where the land of India presses against the rest of Asia, and they hold most of the highest peaks on earth. As you climb, the air grows thinner and colder. A useful rule is that the temperature drops about 3½°F for every 1,000 feet you go up. At the top of Everest each breath has only about a third of the oxygen it would have at sea level, and winds of the jet stream can roar across the summit. That is why climbers carried bottled oxygen, and why the best time to climb is a short calm spell in May, before the monsoon brings heavy snow.

On the map. Everest stands at about 28°N, 87°E, on the border between Nepal and Tibet (part of China). It is about 100 miles east of Kathmandu, the capital of Nepal. The 1953 climbers walked in from Kathmandu for two to three weeks to the Sherpa villages of the Khumbu valley, such as Namche Bazaar, and then on to Base Camp at about 17,600 feet. An **elevation profile** of the route shows the hard truth: the last 3,000 feet, above the South Col, are the steepest and the hardest of all.

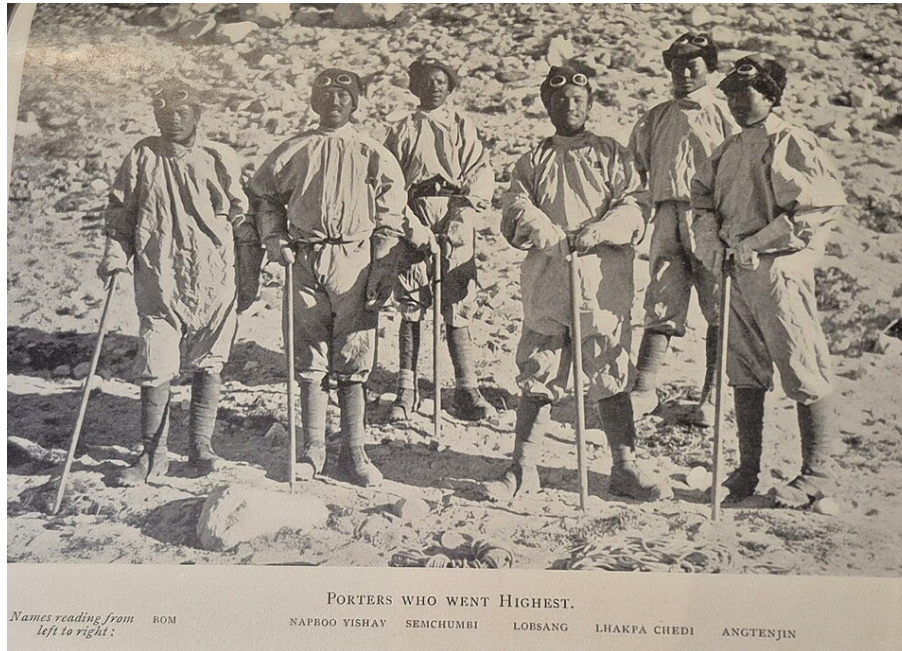


Mount Everest on the border of Nepal and Tibet.



The 1953 route from Base Camp to the summit, shown in side view (distances not to scale).

PICTURE STUDY



The Porters Who Went Highest on Everest in 1924, Unknown photographer, a member of the 1924 British Mount Everest Expedition, 1924 (published 1926) · Black-and-white photograph · Published in Sir Francis Younghusband's *The Epic of Mount Everest* (1926); the photographs of the early Everest expeditions are kept by the Royal Geographical Society, London

In 1924, almost thirty years before Hillary and Tenzing, a British expedition tried to climb Everest from Tibet. Most of the hard work of carrying was done by porters from the hills around Darjeeling, many of them Sherpas. These six men, Bom, Narbu Yishe, Semchumbi, Lobsang, Lhakpa Chedi and Angtenjin, carried tents, food and oxygen higher than any of the other porters that year. Some of them reached the highest camp, more than 26,000 feet up.

Tenzing Norgay began the same way. He first went to Everest as a porter in 1935 and went on six more expeditions before he finally stood on the summit with Hillary in 1953. Hillary always said that the climb was the work of a whole team, and men like these made it possible.

Look closely

- Count the men. Which names from the caption can you match to faces? (They are listed left to right: Bom, Narbu Yishe, Semchumbi, Lobsang, Lhakpa Chedi, Angtenjin.)
- Look at their clothes and boots. What would keep them warm, and what might not be enough at 26,000 feet?
- Look at their faces and the way they stand. How would you describe them: proud, tired, strong, calm?
- Look at the background. What can you tell about where this photograph was taken?

Talk about it

1. Why do you think the expedition wanted a photograph of these men in its book?

2. When we remember a famous climb, why do we often remember only the people who reached the top?
3. Tenzing started as a porter and became one of the first two people to stand on top of the world. What does his story teach about patience and hard work?

PROJECT: A SALT-DOUGH EVEREST AND ITS ELEVATION PROFILE

You will build a model of Everest and its neighbors, mark the 1953 route and camps, and then draw a side view of the route to scale. Seeing the climb from above and from the side shows why the last part was the hardest.

You will need

- Salt dough (2 cups flour, 1 cup salt, about $\frac{3}{4}$ cup water) or modeling clay
- A piece of cardboard about 12 inches square for a base
- Toothpicks and small paper flags for camps
- White paint or flour for snow, and a red marker or yarn for the route
- Graph paper, a ruler and a pencil

Steps

1. Using the map in this lesson and an atlas, shape a long ridge on the cardboard. Build Everest as the highest peak, with Lhotse just to the south and the low saddle of the South Col between them.
2. Press a long, gentle valley into the dough on the south-west side for the Western Cwm, with a jumbled tumble of dough at its mouth for the Khumbu Icefall.
3. Let the dough dry (a day in the air, or a few hours in a low oven with a parent's help), then paint the high parts white.
4. Mark the route with red yarn or marker, and place toothpick flags for Base Camp (about 17,600 ft), the Western Cwm (about 21,000 ft), the South Col (about 26,000 ft), the last camp (about 27,900 ft) and the summit (29,032 ft).
5. On graph paper, draw an elevation profile. Let each square going up stand for 1,000 feet, starting at 15,000 feet. Mark each camp at its elevation, spacing them evenly from left to right, and connect them.
6. Find the steepest part of your profile and label it.

Tips

- Real mountains are much wider than they are tall. Do not make your peak too pointy.
- Your profile is not to scale from left to right, so steepness on it is only a rough guide. Write that under it, as real mapmakers do.

Check your work

- My model shows Everest, Lhotse, the South Col and the Western Cwm.
- All five camps are marked with the right elevations.

- My profile is labeled and shows where the climb gains height fastest.

MAP NOTEBOOK

1. Draw a mountain from the side and color bands for its zones: green forests at the bottom, grass and shrubs above, bare rock, and snow and ice at the top. Write how the temperature changes as you go up.
2. Draw a map of Nepal with Kathmandu, Namche Bazaar and Everest, and an arrow showing the walk in.
3. Make a T-chart: what Hillary brought to the climb, and what Tenzing brought to the climb.

From history. News of the climb reached London on the morning of June 2, 1953, the day Queen Elizabeth II was crowned, and it was announced to the crowds waiting along the route. Hillary was knighted, and Tenzing received the George Medal. Hillary spent much of the rest of his life helping the Sherpa people, and from the early 1960s his Himalayan Trust built schools, clinics and hospitals in the Khumbu valley. Tenzing became director of field training at a new mountaineering school in Darjeeling, training young climbers of India and Nepal.

WORKED EXAMPLES

Example 1. Base Camp lies at about 17,600 feet (5,364 m) and the summit at 29,032 feet (8,849 m). How much higher is the summit than Base Camp, in feet and in meters?

(Use the map or drawing “From Base Camp to the summit is a climb of more than 11,000 feet.” shown earlier in this lesson.)

1. Feet: $29,032 - 17,600 = 11,432$ feet.
2. Meters: $8,849 - 5,364 = 3,485$ meters.
3. Check: $3,485 \text{ m} \times 3.28 \approx 11,430$ feet. The two answers agree.

Answer: About 11,400 feet (about 3,500 m), more than two miles straight up.

Example 2. Hillary and Tenzing left their tent at about 27,900 feet at 6:30 a.m. and reached the summit, 29,032 feet, at about 11:30 a.m. How many feet did they climb, and how many feet per hour was that on average?

1. Height gained: $29,032 - 27,900 = 1,132$ feet.
2. Time: 6:30 to 11:30 is 5 hours.
3. Rate: $1,132 \div 5 \approx 226$ feet per hour.

Answer: They climbed about 1,130 feet at about 226 feet an hour, roughly the height of a 20-story building every hour, on snow and rock, in thin air, wearing heavy oxygen sets.

PRACTICE

1. **EASY** Who were the first two men known to stand on the summit of Everest, and on what date?
2. **EASY** Everest lies on the border of which two lands? What are its Tibetan and Nepali names?
3. **EASY** Who led the 1953 expedition, and which two climbers reached the South Summit three days before Hillary and Tenzing?
4. **MEDIUM** Everest is 29,032 feet high. About how many miles is that? (1 mile = 5,280 feet; round to the nearest half mile.)
5. **MEDIUM** Denali in Alaska, the highest peak in North America, is 20,310 feet high. How much higher is Everest?
6. **MEDIUM** Use the rule that the temperature drops about $3\frac{1}{2}^{\circ}\text{F}$ for every 1,000 feet. If it is 40°F at Namche Bazaar, at about 11,300 feet, about how cold would you expect it to be at the South Col, about 26,000 feet, at the same time?
7. **HARD** Read the elevation profile. Which stretch gains more height: from Base Camp to the Western Cwm, or from the South Col to the summit? By how much?
(Use the map or drawing "Use the profile to compare the two stretches." shown earlier in this lesson.)
8. **CHALLENGE** Hillary and Tenzing agreed for many years to say they reached the top "together." Write a short paragraph explaining why they might have done this, and why both men deserve honor.

COMMON MISTAKES

- Thinking Hillary and Tenzing climbed alone. The climb took a whole expedition of climbers, Sherpas and hundreds of porters.
- Mixing up feet and meters. Everest is 29,032 feet or 8,849 meters, not 29,032 meters.
- Thinking it gets warmer as you climb toward the sun. The air gets colder with height, about $3\frac{1}{2}^{\circ}\text{F}$ for every 1,000 feet.

Make it a game • Climb High, Breathe Slow. Lay ten sheets of paper in a line as camps from Base Camp to the summit. On each sheet a player must answer a question from this unit to move on. From the sixth sheet up (above the South Col), the player must also take three slow steps and three deep breaths between questions, the way high climbers move. If the player misses a question above the South Col, they must go back down one camp, because on a real mountain a mistake up high is the most dangerous. The first to reach the summit plants a paper flag.

Scripture. "In his hand are the deep places of the earth: the strength of the hills is his also." (Psalm 95:4, KJV)

From the floor of the Weddell Sea to the top of Everest, the whole earth belongs to the God who made it. Explorers who reach the highest and lowest places are still standing in His hand.

Practice answers

1. Edmund Hillary of New Zealand and Tenzing Norgay, a Sherpa, on May 29, 1953.
2. Nepal and Tibet (part of China). Tibetan: Chomolungma. Nepali: Sagarmatha.
3. John Hunt led it. Tom Bourdillon and Charles Evans reached the South Summit on May 26.
4. $29,032 \div 5,280 \approx 5.5$, so about $5\frac{1}{2}$ miles.
5. $29,032 - 20,310 = 8,722$ feet higher.
6. Difference in height: $26,000 - 11,300 = 14,700$ feet. $14.7 \times 3\frac{1}{2} \approx 51$ degrees colder. $40 - 51 \approx -11^\circ\text{F}$ (about -11 to -12°F if you round the height to 15,000 feet).
7. Base Camp (17,600) to the Western Cwm (21,000): 3,400 feet. South Col (26,000) to the summit (29,032): 3,032 feet. Base Camp to the Western Cwm gains about 370 feet more, but the stretch above the South Col is far harder because the air is so thin.
8. Sample answer: Reporters and crowds in different countries argued over who stepped on top first, as though one mattered more. The two men knew they were a roped team and that neither could have done it alone, so they refused to divide the honor. Hillary was strong and determined and led much of the final ridge; Tenzing had more experience on Everest than almost anyone, knew the mountain and its weather, and had come within about 800 feet the year before. (In his later autobiography Tenzing told plainly that Hillary had stepped up first.)

UNIT 7 REVIEW

Answer each question. Show your work for calculations and use complete sentences for explanations. Use 1 degree of latitude = 60 nautical miles and 1 nautical mile $\approx$ 1.15 miles. The review is worth 50 points.

1. (4 pts) Who went with Robert Peary on the last stage of his 1909 journey toward the North Pole?
2. (5 pts) Bartlett's support party turned back at about 87°47'N. How many nautical miles were left to the Pole? Show your work.
3. (5 pts) Give two reasons why many people doubt that Peary reached the exact North Pole.
4. (4 pts) Explain the main geographic difference between the North Pole and the South Pole, and say which is colder and why.
5. (4 pts) On what date did Amundsen reach the South Pole, and name two things in his planning that helped his party succeed.
6. (5 pts) Framheim lay at about 78°30'S. How many nautical miles was it in a straight line to the South Pole? About how many ordinary miles?
7. (4 pts) Put these events in order: (a) the *James Caird* reaches South Georgia, (b) the *Endurance* is beset in the Weddell Sea, (c) the *Yelcho* rescues the men on Elephant Island, (d) the *Endurance* sinks, (e) the boats reach Elephant Island.
8. (5 pts) The *James Caird* sailed about 800 nautical miles in 16 days. What was its average distance per day? Why was Worsley's navigation so important?
9. (4 pts) Who reached the summit of Mount Everest on May 29, 1953? Where is Everest (which two lands, and its approximate latitude and longitude)?
10. (5 pts) The South Col is at about 26,000 feet and the summit at 29,032 feet. How much higher is the summit? If the temperature drops about 3½°F for every 1,000 feet, about how much colder is the summit than the South Col?
11. (5 pts) Choose one explorer or team from this unit. In three or four sentences, describe one act of courage or skill and one thing that was wrong, unfair or uncertain in their story.

UNIT PROJECT: MY MAP OF THE ENDS OF THE EARTH

Make two polar-view maps side by side, one centered on the North Pole and one on the South Pole, with rings for latitude every 5 degrees and spokes for longitude. On them draw Peary's route from Cape Columbia, Amundsen's route from Framheim (and Scott's, dashed), and the drift and boat journeys of the *Endurance*. On a third panel, draw the elevation profile of the 1953 Everest route. Add your glove-test results as a bar graph, and write a paragraph answering this question: What did these explorers need most to succeed: courage, skill, planning or honesty? Use at least two of the four stories.

- **Accuracy:** Poles, latitude rings, bases, routes and elevations are placed and labeled correctly, with dates.

- **Measurement:** At least three distances are worked out in nautical miles from degrees of latitude, and the glove test is recorded fairly with a control.
- **Explanation:** The paragraph uses real details from at least two stories and weighs achievement and failure honestly.
- **Care:** The maps, profile and graph are neat, colorful, titled and easy to read, with a key and scale.

Answer key

1. Matthew Henson and four Inuit men: Ootah, Egingwah, Seegloo and Ooqueah.
2. $90^{\circ}00' - 87^{\circ}47' = 2^{\circ}13' = 2 \times 60 + 13 = 133$ nautical miles.
3. Any two: no trained navigator went with him after Bartlett turned back, so no one could check his sightings; the speed he claimed for the last 133 nautical miles was about three times his earlier speed; his records were not opened to full checking for many years. (Some studies support him, so the question remains open.)
4. The North Pole is on drifting sea ice over the deep Arctic Ocean, near sea level. The South Pole is on the continent of Antarctica, on an ice sheet about 9,300 feet high. The South Pole is colder because it is high up and far from the ocean's warmth.
5. December 14, 1911. Any two: dog teams; expert skiing; loose fur clothing learned from the Inuit; depots at 80° , 81° and 82° S marked with lines of flags; a base closer to the Pole; a plan to feed some dogs to the others.
6. $90^{\circ}00' - 78^{\circ}30' = 11^{\circ}30' = 690$ nautical miles. $690 \times 1.15 \approx 790$ miles.
7. (b) January 1915, (d) November 1915, (e) April 1916, (a) May 1916, (c) August 1916.
8. $800 \div 16 = 50$ nautical miles a day. South Georgia is a small island in a huge, stormy ocean; if they missed it, there was no other land nearby to reach, so Worsley's few sun sights with the sextant had to be right.
9. Edmund Hillary and Tenzing Norgay. Everest is on the border of Nepal and Tibet (China), at about 28° N, 87° E.
10. $29,032 - 26,000 = 3,032$ feet, about 3,000 feet. $3.032 \times 3\frac{1}{2} \approx 10.6$, so about 10 to 11° F colder.
11. Answers will vary. Example: Shackleton kept all 28 men of the *Endurance* alive through a shipwreck, an open-boat voyage and a mountain crossing. But the expedition failed in its goal, three men of the Ross Sea party died, and some men, such as the carpenter McNish, were left out of the Polar Medal. Other good answers: Peary's endurance, and his treatment of the Inuit he brought to New York; Henson's skill, and how slowly he was honored.

JUDGING EXPLORERS HONESTLY

All year you have sailed with explorers, navigators and missionaries. Now it is time to weigh them honestly. The Bible tells us God “hath made of one blood all nations of men” (Acts 17:26), and that truth gives us a fair measure for every person in history: neither hiding their courage nor hiding their wrongs. In this unit you will give real credit for things no one had ever done, name real wrongs in plain words, and trace the great exchange of plants, animals and diseases that followed 1492.

You will sail with Columbus on the trade winds in 1492 and home on the westerlies, and see Elcano bring the *Victoria* around the world. You will stand with Bobadilla as he sends Columbus home in chains, read a weeping chronicler’s account of the sale at Lagos in 1444, and hear Antonio de Montesinos preach on Hispaniola in 1511. You will follow the potato from the Andes to Ireland and the horse from Spain to the Great Plains. Finally you will camp with Lewis and Clark at the mouth of the Columbia and write your own essay: **what makes a good explorer?**

BEFORE YOU BEGIN

- Can find places on a map by latitude and longitude in degrees and minutes
- Knows that one degree of latitude is 60 nautical miles and that 15 degrees of longitude is one hour of time (Units 2 and 3)
- Can add and subtract dates and find speed from distance and time
- Can write a clear paragraph with a topic sentence

MASTERY CHECKLIST

- I can tell what Columbus, Magellan and Elcano did that no one had done before, and trace Columbus’s wind loop on a map.
- I can name in plain words the wrongs of Columbus’s rule of Hispaniola, the slave trade the Portuguese began on the African coast, and the Spanish conquests.
- I can name people of that time, such as Montesinos and Las Casas, who said those wrongs were wrong.
- I can name foods, animals and diseases that crossed the Atlantic in each direction and find their homelands on a map.
- I can explain why truth, courage and humility make a good explorer, with real examples.
- I can write a short essay with a claim, three reasons with evidence, and a conclusion.

OPTIONAL BOOKS AND RESOURCES

- ***Landing of Columbus, from the Architect of the Capitol***
(<https://www.aoc.gov/explore-capitol-campus/art/landing-columbus>): Free. A large

image and a short history of John Vanderlyn's painting in the Capitol Rotunda (Lesson 8.1 picture study).

- **The Journals of the Lewis and Clark Expedition (University of Nebraska-Lincoln)** (<https://lewisandclarkjournals.unl.edu/>): Free. The full journals online. A parent can look up the entries for August 12, 1805 (Lemhi Pass) and November 24, 1805 (the vote) to read aloud with Lesson 8.4.

8.1 COURAGE AND SKILL ★

OBJECTIVES

- Tell the story of Columbus's first crossing of the Atlantic in 1492 and of the first voyage around the world (1519–1522), with real dates and places.
- Explain how Columbus used the trade winds going west and the westerlies coming home, and trace that loop on a map.
- Give explorers honest credit for courage and skill while also naming their mistakes, such as Columbus's wrong idea of the size of the earth.

Warm-up. Fill a bowl with water and float a paper boat or a bottle cap. Blow gently across the bowl from one side only. Can your boat sail straight into your breath? Now try to bring it back to where it started without blowing from the other side. (Hint: you may move around the bowl.) Talk about it: how would a sailor get home if the wind always blew one way?

Watch. *Biography of Christopher Columbus for Children: Famous Explorers for Kids - FreeSchool* (Free School, 6:20). <https://www.youtube.com/watch?v=RmRFcXrWKCY>
After the story: follow Columbus's 1492 route from Spain to the Canary Islands and across the Atlantic, and listen for the names of his three ships.

Note: Captions were not available to check; preview it first. Children's biographies of Columbus often talk about how he treated the native people, so check how this one frames it.

Backup video. *Christopher Columbus for Kids / Little Patriots Course 1* (Little Patriots, 6:55). <https://www.youtube.com/watch?v=wKaRsJlcPvU>
After the story: listen for the Niña, the Pinta and the Santa María and for why Columbus sailed west. Note: Captions were not available to check; preview it first. This series takes a strongly patriotic approach to history, so check that it stays on the voyage.

KEY TERMS

courage

Doing what is right or needed even when you are afraid and the danger is real.

seamanship

The skill of handling a ship and crew: reading the wind and weather, steering, and keeping everyone alive.

trade winds

Steady winds that blow from the northeast toward the equator in the northern Atlantic, carrying ships west.

westerlies

Winds farther north, at about the latitude of Spain and the Azores, that blow from the west and carry ships east toward Europe.

circumnavigation

A voyage all the way around the world.

CORE IDEAS

The story. Early on August 3, 1492, three small ships slipped out of the harbor of Palos in southern Spain. They were the *Niña*, the *Pinta* and the *Santa María*, with about 90 men aboard, led by a sailor from Genoa named Christopher Columbus. They sailed south to the Canary Islands, and on September 6 they left the island of Gomera and pointed their bows due west, into an ocean no European ship had crossed. The men grumbled and grew afraid. Columbus kept his own count of the miles sailed and told the crew a smaller number, so they would not lose heart at how far from home they were. At about two o'clock in the morning on October 12, a lookout on the *Pinta* named Rodrigo de Triana saw a pale strip of land shining in the moonlight. At dawn they rowed ashore on an island its people called Guanahani. Columbus named it San Salvador.

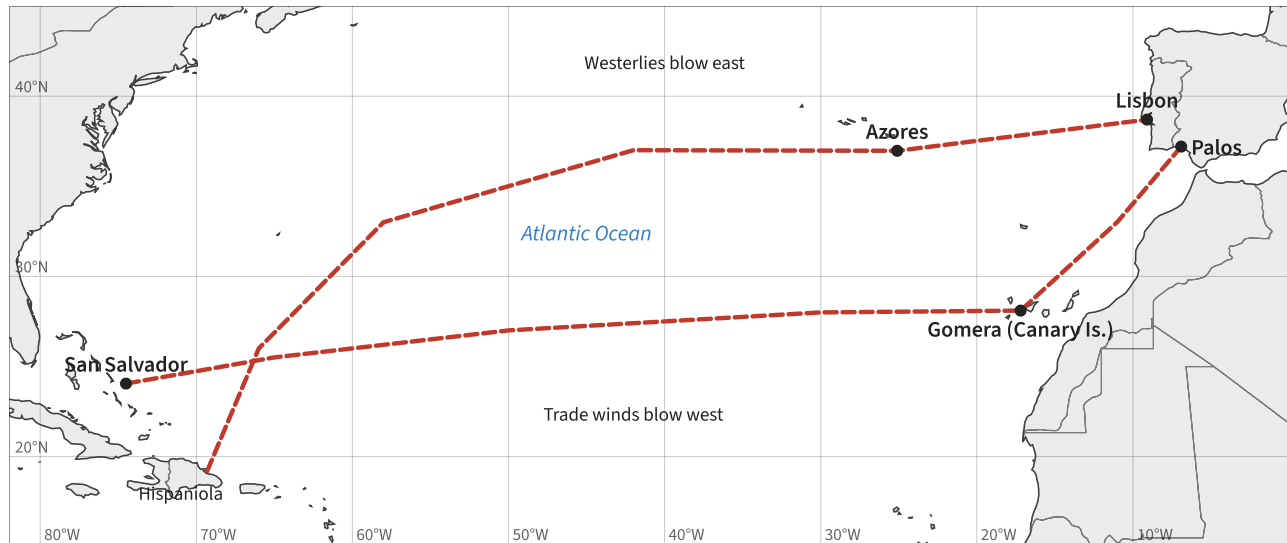
How they figured it out. Columbus's great skill was reading the wind. He had sailed with the Portuguese down the coast of Africa, and he knew that near the Canary Islands the wind blows steadily from the northeast. These are the **trade winds**, and that is why he sailed south before turning west: the wind would push him across. But how would he get home against that same wind? On the way back in early 1493 he sailed north to about the latitude of the Azores, where the **westerlies** blow toward Europe. He steered by compass, judged his speed by watching the water slide past (dead reckoning, from Unit 2), and checked his latitude by the North Star. After surviving a fierce winter storm, he reached Lisbon on March 4 and Palos on March 15, 1493. Sailing ships still cross the Atlantic by this same loop.

Honest about mistakes. Columbus did not prove the earth was round. Educated people had known that since the ancient Greeks. The question was how *big* the earth was. Columbus thought Japan lay only about 2,400 nautical miles west of the Canaries. The experts who advised the king and queen of Spain said the ocean was far wider, and they were right: the real distance is more than 10,000 nautical miles. Columbus would have run out of food and water long before reaching Asia if two continents had not been in the way. To his death he insisted he had reached the Indies, which is why he called the people "Indians." Nor was he the first to arrive. Norse sailors under Leif Erikson had reached Newfoundland about the year 1000, and millions of people already lived in the Americas. What Columbus did first was a round trip that joined the two halves of the world for good.

The big idea. Others also did what no one had done. In 1519 Ferdinand Magellan led five ships from Spain, found a twisting strait at the southern tip of South America, and crossed the Pacific, an ocean so wide that his men ate leather and sawdust before they reached land. Magellan was killed in the Philippines in 1521, but Juan Sebastián Elcano brought one ship, the *Victoria*, home to Spain in September 1522 with only 18 of the original men. It was the first ship to sail around the world. **Courage** means going on when the danger is real. **Skill**

means knowing your craft so well that you can bring your crew home. Judging explorers honestly begins with giving credit where it is due.

On the map. Look at the map of Columbus's first voyage. Trace the outward route from Palos south to the Canaries at about 28°N , then west across the ocean to San Salvador at about 24°N . Now trace the homeward route north to the Azores at about 37°N and east to Lisbon. The two routes make a great loop, like a wheel turning clockwise, because God set the winds of the North Atlantic turning that way.



Columbus's first voyage, 1492-1493: out with the trade winds, home with the westerlies.

PICTURE STUDY



Landing of Columbus, John Vanderlyn, 1847 (placed in the Rotunda) · Oil on canvas, about 12 by 18 feet · Rotunda of the United States Capitol, Washington, D.C.

John Vanderlyn was an American painter from Kingston, New York, who had studied in Paris. Congress asked him to paint one of the great history pictures for the Rotunda of the Capitol, and he chose the moment on October 12, 1492, when Columbus stepped ashore on Guanahani. The painting was hung in 1847. It became so famous that it was printed on a United States stamp for the World's Columbian Exposition in 1893.

Vanderlyn painted 355 years after the landing, and no one in the picture sat for him. It shows how Americans of the 1840s imagined the scene: brave, solemn and grand. As you look, ask what the painter shows clearly and what he leaves in the shadows.

Look closely

- Find Columbus. What is he holding, and why might he have taken off his hat?
- Find the sailors. What are some of them doing on the sand? What might they be looking for?
- Look at the right side of the picture. Who is watching from behind the trees, and how large are they compared with the Spaniards?
- Find the ships in the background. How big do they look next to the ocean they had just crossed?

Talk about it

1. What does this painting want you to feel about Columbus? Which parts of today's lesson does it show well?
2. The people of Guanahani are small and half hidden. If they had painted this day, what might they have put in the middle?
3. Is a painting the same as a photograph? What should we remember when we use paintings to learn history?

PROJECT: THE WIND WHEEL: SAILING THE ATLANTIC LOOP

You will make a tabletop map of the North Atlantic, set the winds blowing the way God made them blow, and sail a paper ship from Spain to the Caribbean and home again using only the wind. You will feel why Columbus went south first and north to come home.

You will need

- A large sheet of paper or poster board (or the lid of a big box)
- Markers or crayons, and a ruler
- A world map or atlas to copy from
- A paper boat or bottle-cap boat with a small paper sail
- A drinking straw for each sailor
- Two strips of blue paper or blue yarn, and tape

Steps

1. Draw the outline of the North Atlantic: Spain and Portugal and the bulge of Africa on the right, the Caribbean islands and Florida on the left. Mark Palos, the Canary Islands, San Salvador, the Azores and Lisbon.
2. Draw latitude lines for 20°N, 30°N and 40°N across the map.
3. Tape a blue strip across the southern half, from near the Canaries toward the Caribbean. Draw arrows on it pointing west and a little south, and label it “Trade winds.”
4. Tape a second blue strip across the northern half, from near Bermuda toward the Azores and Spain, with arrows pointing east. Label it “Westerlies.”
5. Put your boat at Palos. Try to blow it straight west from Spain at 37°N, but you may only blow in the direction of the arrows nearest the boat. What happens?
6. Now start again: blow it south to the Canaries, then west along the trade winds to San Salvador. Then move north to the westerlies and blow it home. Count your breaths for each leg.
7. Draw the whole loop on your map in red and add a small drawing of the *Niña*, the *Pinta* and the *Santa María*.

Tips

- Blow gently through the straw so the boat glides instead of flipping.
- Real winds shift, and Columbus also met calms and storms. The arrows show the usual pattern, not every day’s weather.

Check your work

- I can show on a map why Columbus sailed south before sailing west.
- I can name the winds he used going out and coming home.
- I can trace the clockwise loop of winds in the North Atlantic.

MAP NOTEBOOK

1. Copy the map of Columbus’s first voyage into your map notebook. Label Palos, Gomera, San Salvador, the Azores and Lisbon, and write the latitude of each in whole degrees.
2. Draw a two-column chart titled “Columbus, Honestly.” In one column list three things he did with courage and skill. In the other list two things he got wrong.
3. Draw the *Victoria* and write one sentence about why her voyage was something no one had ever done.

From history. Columbus’s original logbook of the first voyage has been lost. What we have is a long summary made by the friar Bartolomé de las Casas, who copied and condensed it in the 1500s, sometimes quoting Columbus’s own words. You will meet Las Casas again in the next lesson, because he became one of the bravest critics of how the Spanish treated the people of the islands.

WORKED EXAMPLES

Example 1. Columbus left Gomera in the Canary Islands on September 6, 1492, and landed on San Salvador on October 12. The distance is about 3,100 nautical miles. How many days did the crossing take, and about how many nautical miles did the fleet sail each day? What was its average speed in knots?

(Use the map or drawing “Find Gomera and San Salvador on the outward route.” shown earlier in this lesson.)

1. Count the days. From September 6 to September 30 is 24 days (September has 30 days). Then add the 12 days of October: $24 + 12 = 36$ days.
2. Divide distance by days: $3,100 \div 36 \approx 86$ nautical miles per day.
3. A knot is one nautical mile per hour. There are 24 hours in a day: $86 \div 24 \approx 3.6$ knots.
4. To change to land miles, multiply by about 1.15: $3,100 \times 1.15 \approx 3,600$ miles (about 5,700 km).

Answer: 36 days; about 86 nautical miles a day; about 3.6 knots, a fast walking pace. The whole crossing was about 3,600 miles (5,700 km).

Example 2. Palos is at about 37°N and Gomera is at about 28°N . How far south did Columbus sail to reach the trade winds? Give your answer in nautical miles and in miles. (Remember: one degree of latitude is 60 nautical miles.)

(Use the map or drawing “Compare the latitudes of Palos and Gomera.” shown earlier in this lesson.)

1. Subtract the latitudes: $37^\circ - 28^\circ = 9^\circ$.
2. Multiply by 60 nautical miles per degree: $9 \times 60 = 540$ nautical miles.
3. Change to land miles: $540 \times 1.15 \approx 620$ miles (about 1,000 km).
4. This is only the north-south part of the trip, because Gomera is also a little west of Palos. The real sailing distance was a bit longer.

Answer: 9° of latitude, which is 540 nautical miles, or about 620 miles (1,000 km) south.

PRACTICE

1. **EASY** On what date did Columbus’s ships first reach land in the Americas, and what name did Columbus give the island?
2. **EASY** Name the three ships of Columbus’s first voyage.
3. **MEDIUM** Magellan’s fleet left the strait at the tip of South America on November 28, 1520, and reached the island of Guam on March 6, 1521. How many days did they spend crossing the Pacific? (1521 was not a leap year.)

4. **MEDIUM** Look at the map. Coming home in January 1493, Columbus left Hispaniola at about 19°N and sailed northeast until he reached the Azores at about 37°N. How many degrees north did he climb to find the westerlies, and how many nautical miles is that? *(Use the map or drawing “Find where the homeward route begins and where it passes the Azores.” shown earlier in this lesson.)*
5. **MEDIUM** Columbus believed Japan was about 2,400 nautical miles west of the Canary Islands. The true distance is about 10,600 nautical miles. About how many times larger is the true distance?
6. **HARD** If Columbus’s fleet averaged 86 nautical miles a day, how many days would it have taken to sail the 2,400 nautical miles he expected? Why do you think his crew grew frightened after about a month at sea?
7. **HARD** The Norse site at L’Anse aux Meadows in Newfoundland is at about 52°N. San Salvador is at about 24°N. Which is farther north, and by how many degrees? About how many nautical miles is that?
8. **CHALLENGE** In three or four sentences, explain this puzzle: the experts who told the king and queen of Spain that the ocean was too wide to cross were right, and yet Columbus’s voyage succeeded. What does this teach about courage and about being honest with facts?

COMMON MISTAKES

- Thinking Columbus proved the earth was round. Educated Europeans already knew that; the argument was about how big the earth was, and Columbus was wrong about that.
- Saying Columbus was the first person in the Americas. Millions of people already lived there, and Norse sailors had reached Newfoundland about 500 years earlier.
- Thinking Magellan sailed all the way around the world. He was killed in the Philippines in 1521; Juan Sebastián Elcano brought the *Victoria* home.

Make it a game • Trade Winds and Westerlies. Lay out a big loop in the yard or living room with string or tape: Spain at the top right, the Canaries below it, the Caribbean on the left. One player is the Wind Caller. When the caller shouts “Trade winds!” sailors may only move west along the southern part of the loop; “Westerlies!” means only east along the northern part; “Calm!” means freeze. A sailor caught moving the wrong way goes back to Palos. The first to sail the whole loop and touch Spain again names one real explorer and one thing he did that no one had done before.

Scripture. “Have not I commanded thee? Be strong and of a good courage; be not afraid, neither be thou dismayed: for the LORD thy God is with thee whithersoever thou goest.” (Joshua 1:9, KJV)

Courage is not the absence of fear but doing the right thing in spite of it. Sailors on the open ocean knew how small they were; true courage rests on the God who is with us wherever we go.

Practice answers

1. October 12, 1492. He named the island San Salvador (its people called it Guanahani).
2. The *Niña*, the *Pinta* and the *Santa María*.
3. November 28 to 30 is 2 days, then December 31 + January 31 + February 28 + March 6 = 96.
Total $2 + 96 = 98$ days.
4. $37^\circ - 19^\circ = 18^\circ$, and $18 \times 60 = 1,080$ nautical miles (about 1,240 miles).
5. $10,600 \div 2,400 \approx 4.4$, so the true distance is more than 4 times what Columbus believed.
6. $2,400 \div 86 \approx 28$ days. By the fifth week they had sailed farther than Columbus had promised and still saw no land, so they feared they would run out of food and water or never get home against the wind.
7. L'Anse aux Meadows is farther north by $52^\circ - 24^\circ = 28^\circ$, which is $28 \times 60 = 1,680$ nautical miles.
8. The experts were right that Asia was much farther than Columbus thought; he would have run out of food long before reaching it. His voyage succeeded only because unknown continents lay in between. His courage and seamanship were real, but his numbers were wrong. An honest judge gives credit for courage and skill without pretending the explorer was right about everything.

8.2 REAL WRONGS

OBJECTIVES

- Describe plainly what went wrong under Columbus's rule of Hispaniola (1493–1500) and why he was sent home in chains.
- Explain how the Atlantic slave trade began with Portuguese raids and purchases on the African coast in the 1440s, and how the conquests of the Aztec and Inca empires happened.
- Show that these wrongs were named as wrongs by Christians at the time, such as Antonio de Montesinos and Bartolomé de las Casas, and judge them by the truth that God made all nations of one blood.

Warm-up. Your parent reads two short reports of the same soccer game: one written by a fan of the winning team, one by a fan of the losing team (make them up together in two minutes). What did each writer leave out? Talk about it: if you wanted the whole truth about the game, what would you do?

Video. Coming soon. Columbus as governor of Hispaniola, Bartolomé de las Casas and Antonio de Montesinos, the beginning of the Atlantic slave trade, and the Spanish conquest of the Aztecs and Incas: search The History Guy, Drive Thru History, Smithsonian and Library of Congress (a parent should preview, since some videos show violence).

KEY TERMS

governor

A person appointed to rule a colony or province on behalf of a king or government.

tribute

Goods or money that conquered people are forced to pay to their rulers.

slave trade

The business of capturing, buying and selling human beings as property.

conquest

Taking control of a land and its people by force.

conscience

The inner sense, given by God, that tells us right from wrong.

Taíno

The native people of Hispaniola, Puerto Rico, Cuba and the Bahamas whom Columbus met in 1492.

CORE IDEAS

The story. In August 1500 a royal official named Francisco de Bobadilla sailed into the harbor of Santo Domingo on the island of Hispaniola. King Ferdinand and Queen Isabella of Spain had sent him because so many complaints had reached them about the island's governor: Christopher Columbus. Within weeks Bobadilla had Columbus and his brothers put in chains and shipped back to Spain. The great admiral of 1492 came home a prisoner. The king and queen soon released him, but they never let him govern again. What had happened?

What went wrong. In 1493 Columbus returned with 17 ships and more than 1,200 men, sent to settle the island and find gold. As governor, he ordered every Taíno aged fourteen or older in the gold country to bring a small hawk's bell full of gold dust every three months. People who could not pay were punished harshly. In 1495 he shipped about 500 Taíno captives to Spain to be sold as slaves; about 200 died on the voyage. Queen Isabella was angry that her new subjects were being sold, and she later ordered those who had been sold to be freed and sent home. Many Spanish settlers also complained of cruel punishments. Columbus was a brave sailor but a poor and harsh ruler. Within a few decades very few Taíno were left on Hispaniola, killed mostly by new diseases (Lesson 8.3), but also by overwork, hunger and war.

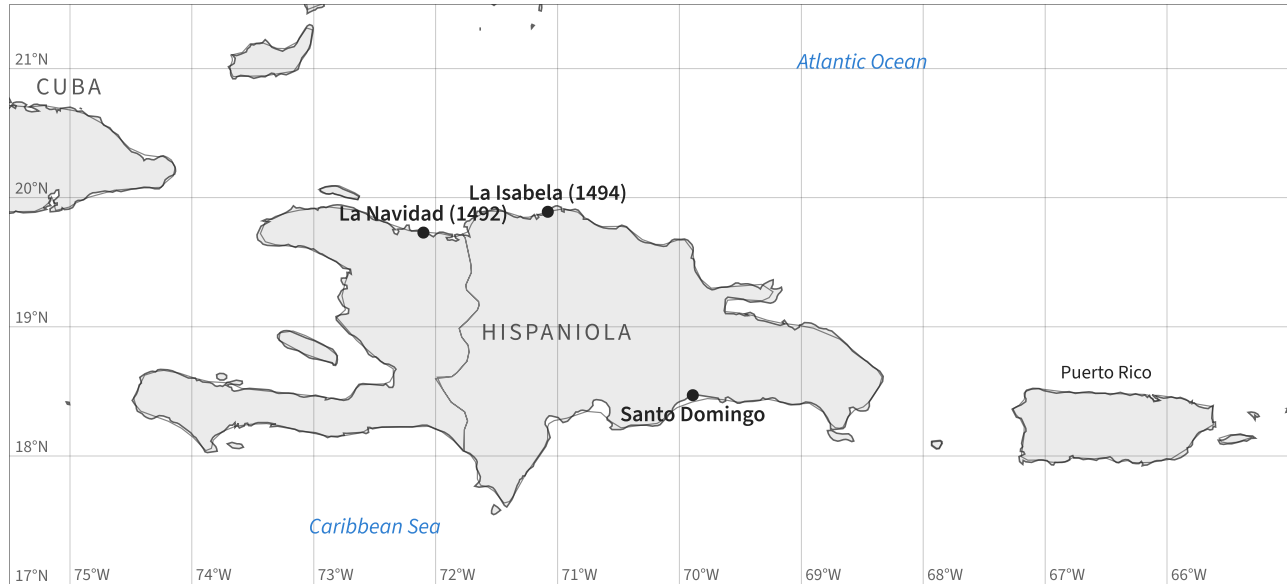
The slave trade. Buying and selling people across the ocean did not begin with Columbus. It began with the Portuguese on the coast of Africa. In August 1444, at the port of Lagos in southern Portugal, more than two hundred Africans captured on the coast to the south were unloaded and sold in a field. The royal chronicler Gomes Eanes de Zurara described mothers and children being pulled apart, and he wrote that he wept at the sight. Prince Henry the Navigator, whom you met in Unit 1, took a share of the captives. Soon African rulers and merchants were selling captives to the Portuguese too. Later, traders carried Africans across the Atlantic to work on sugar plantations in Brazil and the Caribbean. From the 1500s to the 1860s about 12.5 million Africans were put on slave ships, and about 10.7 million lived to reach the Americas.

Conquest. Spanish soldiers went on to conquer two great empires. Between 1519 and 1521 Hernán Cortés, helped by thousands of native allies who hated Aztec rule, captured the Aztec capital of Tenochtitlan. In 1532 Francisco Pizarro seized the Inca ruler Atahualpa at Cajamarca, took a room full of gold and silver as his ransom, and then had him killed anyway in 1533. The Aztecs and Incas had conquered their own neighbors, and the Aztecs sacrificed captives to their gods, but those wrongs did not make Pizarro's broken promise right.

Judged by the truth. Some say people back then did not know better. They did. In December 1511, on Hispaniola, a friar named Antonio de Montesinos preached to the settlers that they were in deadly sin for their cruelty, and asked whether the Taíno were not men with souls, to be loved as themselves. A young settler-priest named Bartolomé de las Casas, who had Taíno laborers of his own, was stung by conscience. In 1514 he gave them up and spent the next fifty years defending the native peoples. Once he suggested bringing Africans to do the work instead, and later he wrote that he bitterly regretted it. The standard

was not a modern opinion. It was God's word: man-stealing was forbidden in the law of Moses, and all nations are made "of one blood."

On the map. Find Hispaniola on the map. La Navidad, the first Spanish fort, was on the north coast; La Isabela was Columbus's town of 1494; Santo Domingo on the south coast became the capital. The island is shared today by Haiti and the Dominican Republic.



Hispaniola in the 1490s, where Columbus was governor.

PICTURE STUDY



Portrait of a Man, Said to Be Christopher Columbus, Sebastiano del Piombo, 1519 · Oil on canvas · The Metropolitan Museum of Art, New York

Sebastiano del Piombo was a Venetian painter who worked in Rome alongside Michelangelo. He painted this portrait in 1519, thirteen years after Columbus died. An inscription on the painting says it shows Columbus, but experts think the words were added later. No portrait of Columbus painted while he was alive is known to survive.

So the man most famous for the voyage of 1492 is a man whose face we do not truly know. That is a good lesson for judging history: we must sort what we know from what we have been told, and be honest about the difference.

Look closely

- Look at the man's face. What words would you use for his expression?
- Look at his clothes and his hands. Do they tell you he was a sailor, a ruler or a scholar?
- Find the lettering on the painting. Why does it matter whether those words were added later?

Talk about it

1. Compare this serious man with the heroic Columbus in Vanderlyn's painting from Lesson 8.1. Which do you trust more, and why?
2. If you could ask the painter one question about this portrait, what would it be?

PROJECT: TWO COLUMNS OF TRUTH

Honest historians do not write only praise or only blame. You will make a large two-column poster about one explorer or conqueror from this unit, with real facts and dates in each column, and a source for each fact from this lesson or a book.

You will need

- Poster board or two sheets of paper taped together
- Ruler, markers or colored pencils
- This lesson, Lesson 8.1, and a children's encyclopedia or library book on exploration
- Index cards

Steps

1. Choose one person: Columbus, Henry the Navigator, Cortés or Pizarro.
2. Draw a line down the middle of the poster. Title the left column "Courage and Skill" and the right column "Real Wrongs."
3. On index cards, write at least three true facts for each column. Each card must include a date and a place (for example: "1495, Hispaniola: sent about 500 Taíno to Spain as slaves").
4. Under each fact write where you found it (the lesson, or the title of the book and the page).
5. Glue the cards in order of date in each column.

6. At the bottom, write the name of one person from the time who spoke up for what was right (Montesinos, Las Casas or Queen Isabella) and what that person did.
7. Finish with one sentence of your own: “An honest judgment of ___ is ...”

Tips

- Use plain words. “He sold people as slaves” is clearer than vague phrases.
- If two books disagree about a number, write “about” and give the smaller round number, or note that books disagree.

Check your work

- Every fact has a date, a place and a source.
- Both columns are honest and complete.
- I named someone from that time who called the wrong a wrong.

MAP NOTEBOOK

1. Copy the map of Hispaniola. Mark La Navidad, La Isabela and Santo Domingo, and write the year each was founded or built (La Navidad 1492, La Isabela 1494, Santo Domingo in the 1490s).
2. Draw the coast of West Africa and Portugal. Mark Lagos (Portugal) and Cape Bojador, and write the date 1444 beside Lagos.
3. Write a sentence about Bartolomé de las Casas and draw a small picture of him writing at a desk.

From history. In 1542, after years of pleading by Las Casas and others, King Charles I of Spain signed the New Laws, which forbade making native people of the Americas slaves. Many settlers fought against the laws, and parts were weakened, but they were among the first laws by a European government to protect the native peoples of a colony. Las Casas’s book *A Short Account of the Destruction of the Indies* was printed in Seville in 1552.

WORKED EXAMPLES

Example 1. Portuguese caravels sailed from Lagos, Portugal, at about 37°N , south past Cape Bojador on the African coast at about 26°N . How many nautical miles south is Cape Bojador from Lagos? About how many miles is that?

1. Subtract the latitudes: $37^{\circ} - 26^{\circ} = 11^{\circ}$.
2. Each degree of latitude is 60 nautical miles: $11 \times 60 = 660$ nautical miles.
3. Change to land miles: $660 \times 1.15 \approx 760$ miles (about 1,200 km).

Answer: 11° of latitude: 660 nautical miles, or about 760 miles (1,200 km). The raiders of the 1440s sailed even farther south than this.

Example 2. Use the map of Hispaniola. La Isabela is at about 19°53'N and Santo Domingo is at about 18°28'N. How far apart are they in latitude, and how many nautical miles is that north to south? In which general direction is Santo Domingo from La Isabela?

(Use the map or drawing “Find La Isabela on the north coast and Santo Domingo on the south coast.” shown earlier in this lesson.)

1. Subtract degrees and minutes: $19^{\circ}53' - 18^{\circ}28'$. Minutes first: $53' - 28' = 25'$. Degrees: $19^{\circ} - 18^{\circ} = 1^{\circ}$. Difference: $1^{\circ}25'$.
2. One degree is 60 nautical miles and one minute is 1 nautical mile: $60 + 25 = 85$ nautical miles.
3. On the map, Santo Domingo is lower (south) and to the right (east) of La Isabela.

Answer: $1^{\circ}25'$ of latitude, or 85 nautical miles north to south (about 100 miles). Santo Domingo is to the southeast of La Isabela.

PRACTICE

1. **EASY** Who arrested Columbus on Hispaniola, and in what year?
2. **EASY** What tribute did Columbus demand from the Taíno in the gold country?
3. **MEDIUM** The first large sale of captured Africans in Portugal took place at Lagos in 1444. Columbus first crossed the Atlantic in 1492. How many years apart are these events?
4. **MEDIUM** About 12.5 million Africans were put on slave ships bound for the Americas, and about 10.7 million survived the voyage. About how many died at sea?
5. **MEDIUM** Look at the map. Name the first Spanish fort in the Americas, built from the wreck of the *Santa María* on Christmas 1492. On which coast of Hispaniola was it?
(Use the map or drawing “Find the fort on the north coast.” shown earlier in this lesson.)
6. **HARD** Tenochtitlan, the Aztec capital, was at about 19°N. Cuzco, the Inca capital, is at about 14°S. How many degrees of latitude apart are they, and how many nautical miles is that north to south?
7. **HARD** Name two people living at the time who said that the treatment of native peoples was wrong, and tell what each one did.
8. **CHALLENGE** Someone says, “You can’t blame explorers for slavery and cruelty, because nobody back then thought it was wrong.” Write three or four sentences answering this honestly.

COMMON MISTAKES

- Thinking Columbus started the slave trade from Africa. The Portuguese began buying and capturing Africans on the West African coast in the 1440s, about fifty years before 1492.
- Telling only one side. Columbus had real courage and real skill (Lesson 8.1) and also did real wrongs as governor. Honest history tells both.

- Thinking no one at the time objected. Montesinos, Las Casas and others protested loudly, and Queen Isabella ordered slaves freed.

Make it a game · Who Said It Was Wrong?. Write these names on cards: Zurara, Montesinos, Las Casas, Queen Isabella, Bobadilla. A parent reads a clue (for example, “I preached on Hispaniola in 1511,” or “I wept at the sale in Lagos,” or “I arrested Columbus”). The first player to hold up the right card wins a point and must say the year and the place. Play until every card has been won twice.

Scripture. “And hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation;” (Acts 17:26, KJV)

Paul spoke these words in Athens to people who thought themselves better than other nations. The Taíno, the Africans sold at Lagos and the Spanish sailors were all of one blood, made by one God. That truth is the standard by which these wrongs are judged.

Practice answers

1. Francisco de Bobadilla, sent by King Ferdinand and Queen Isabella, in 1500.
2. Every person fourteen or older had to bring a small hawk’s bell full of gold dust every three months.
3. $1492 - 1444 = 48$ years.
4. $12.5 \text{ million} - 10.7 \text{ million} = \text{about } 1.8 \text{ million people.}$
5. La Navidad, on the north coast of Hispaniola (in today’s Haiti).
6. One is north of the equator and one is south, so add: $19^\circ + 14^\circ = 33^\circ$. That is $33 \times 60 = 1,980$ nautical miles.
7. Any two: Antonio de Montesinos preached against the settlers’ cruelty on Hispaniola in 1511; Bartolomé de las Casas gave up his own laborers in 1514 and spent fifty years defending the native peoples; Queen Isabella ordered Taíno who had been sold as slaves to be freed and sent home.
8. That is not true. In 1444 the chronicler Zurara wept at the sale in Lagos; in 1511 Montesinos preached that the settlers were sinning; Las Casas gave up his laborers and spent his life defending the Taíno; Queen Isabella freed Taíno who had been sold. The Bible had long forbidden man-stealing and taught that all nations are of one blood. So these were wrongs by the standard people knew then, not only by ours.

8.3 EXCHANGE ACROSS THE OCEAN

OBJECTIVES

- Name plants, animals and diseases that crossed the Atlantic in each direction after 1492, and say where each came from.
- Explain how the Columbian Exchange changed what people eat and how they live on every continent, for good and for grief.
- Use latitude and longitude to compare the homelands of crops such as the potato with the places they spread to.

Warm-up. Open your refrigerator and pantry with a parent. Pull out five foods. For each one, guess: did it first grow in the Americas, or in Europe, Africa and Asia? Put the guesses in two piles and keep them until the end of the lesson to check.

Watch. *The COLUMBIAN EXCHANGE, Explained [AP World History Review—Unit 4 Topic 3]* (Heimler's History, 5:07). <https://www.youtube.com/watch?v=6zo9XQD86uU>
After the story: watch this five-minute overview and list the foods, animals and diseases that crossed the ocean each way.

Note: Captions were not available to check; preview it first. It is a fast-paced high school (AP) review that talks about smallpox deaths and forced labor, and it opens and closes with ads for the channel's study guides.

Backup video. *The Columbian Exchange [AP World History] Unit 4 Topic 3* (Heimler's History, 5:50). <https://www.youtube.com/watch?v=XrF6TDzsGuA>

As review: watch and sort what went from the Americas to Europe (maize, potatoes, manioc) and what came the other way (horses, cattle, sugar, smallpox). Note: Captions were not available to check; preview it first. It is a high school (AP) review that covers smallpox deaths among Native Americans, and the channel advertises its study guides.

KEY TERMS

Columbian Exchange

The movement of plants, animals, people and diseases between the Americas and the rest of the world that began with Columbus's voyages of 1492–1493.

Old World

Europe, Africa and Asia, the lands Europeans knew before 1492.

New World

The Americas, as Europeans called them after 1492.

native plant

A plant that grew wild or was first farmed in a place, rather than being brought from elsewhere.

immunity

The body's power to fight off a disease, often built up after people have met that disease before.

blight

A plant disease that makes leaves and roots wither and rot, like the blight that struck Ireland's potatoes in 1845.

CORE IDEAS

The story. On September 25, 1493, Columbus sailed from Cádiz in Spain with 17 ships on his second voyage. This time he was not just exploring. He was carrying a whole farm across the ocean. In the Canary Islands he took on sugarcane cuttings, seeds and animals, including pigs, and his ships carried horses, cattle, goats and sheep. On November 3 the fleet sighted the island of Dominica. No horses, cattle or pigs lived anywhere in the Americas in 1492. Within a hundred years they roamed from Mexico to Argentina. Going the other way, Spanish sailors carried home strange new foods: maize, chili peppers and, later, the potato.

How it worked. For thousands of years the Americas and the Old World had been separated by wide oceans, so each had its own plants, animals and diseases. The Americas gave the world **corn** (maize), **potatoes**, tomatoes, beans, squash and pumpkins, peanuts, chili peppers, cacao for chocolate, vanilla, pineapples, cassava, sweet potatoes, turkeys and tobacco. The Old World sent **horses**, cattle, pigs, sheep, goats and chickens; wheat, rice, oats and barley; sugarcane, coffee, bananas, oranges, onions, grapes and honeybees. In 1972 a historian named Alfred Crosby gave this great swap a name: the **Columbian Exchange**.

Foods that changed the world. The potato was first farmed high in the Andes Mountains near Lake Titicaca. It grows well in cool, rainy places, and it fed millions in Ireland, Germany, Poland and Russia. When a blight rotted Ireland's potato crop in 1845, about a million people died in the famine that followed and about a million more left, many for America. Corn from Mexico became a main food in much of Africa. Tomatoes went into Italian sauce and chili peppers into the cooking of India and Thailand. In the Americas, horses changed the life of the Great Plains: by the 1700s the Comanche and the Lakota had become some of the finest horsemen in the world. Cattle spread over the grasslands of Argentina and Texas. But sugarcane also brought sorrow: the sugar plantations of Brazil and the Caribbean were where most enslaved Africans were sent (Lesson 8.2).

The hidden passengers. The saddest part of the exchange could not be seen. Sailors and settlers carried smallpox, measles and influenza. People in the Old World had lived with these diseases for centuries, and many had some immunity. The peoples of the Americas had never met them. In 1520 smallpox swept through Tenochtitlan and killed many thousands, including the Aztec ruler Cuitláhuac. In many places most of the native people died within a hundred years. No one at that time understood germs, and most of these deaths were not planned by anyone, but they were real and terrible, and they help explain how small Spanish forces could conquer great empires.

The big idea. God filled the earth with "every herb bearing seed" and gave it to people for food. When the two halves of the world met, the gifts of each became gifts to all. Today corn

grows on every inhabited continent, and the potato is one of the world's most important food crops. Yet the same ships carried disease and the sugar that drove the slave trade. An honest historian sees both the blessing and the grief.

On the map. Study the map of plants and animals crossing the Atlantic. Follow the arrows from the Andes and Mexico to Europe and Africa, and from Spain and West Africa to the Caribbean and Brazil.



Plants and animals crossing the Atlantic after 1492.

PICTURE STUDY



The Potato Eaters, Vincent van Gogh, April–May 1885 · Oil on canvas · Van Gogh Museum, Amsterdam

Vincent van Gogh painted this picture in the spring of 1885 in the Dutch village of Nuenen, where he lived among farm families. He wanted to show peasants eating the potatoes they had dug from the ground with the very hands they were now putting into the dish. He thought it was one of his most important paintings.

Look at the plate in the middle. About three hundred years earlier, no one in the Netherlands had ever eaten a potato. The humble food on this table had traveled from the Andes Mountains of South America, across the Atlantic, to become the daily bread of poor families all over northern Europe.

Look closely

- Find the lamp. How does its light fall on the faces and hands?
- Find the potatoes and the coffee. Where in the world did each first grow? (Potatoes: the Andes. Coffee: Africa.)
- Look at the hands. What do they tell you about the work these people did?
- Count the people. How do they share the meal?

Talk about it

1. Why might Van Gogh have chosen dark, earthy colors for this painting?
2. How would this family's supper have been different if the potato had never crossed the ocean?
3. Why do you think the potato became so important to poor farm families in cool, rainy countries?

Safety first. Ask an adult before tasting chili peppers, and wash your hands after touching them. Check for peanut or other food allergies before the tasting meal.

PROJECT: A COLUMBIAN EXCHANGE CHART WITH REAL FOODS

You will build a big chart of the Columbian Exchange using real foods from your kitchen and the grocery store, place each food on a map at its homeland, and finish with a tasting meal that uses gifts from both sides of the ocean.

You will need

- A large sheet of poster board
- A printed or hand-drawn outline map of the world
- Real foods or their labels and wrappers: for example a potato, an ear of corn or cornmeal, a tomato, dried beans, a small pumpkin or squash, peanuts, chocolate, a chili pepper; and wheat flour, rice, a banana, an orange, an onion, sugar, coffee beans and a picture of a horse, cow, pig and chicken
- Yarn or string in two colors, tape and glue
- Index cards and markers

Steps

1. Draw a line down the middle of the poster. Title the left side “From the Americas to the World” and the right side “From the Old World to the Americas.” Glue the world map across the top.
2. Sort your foods into the two sides. Check each one with this lesson.
3. For each food, make an index card with its name, its homeland (for example, “Potato: the Andes, near Lake Titicaca”) and one country where it is now an everyday food.
4. Tape the real food, wrapper or a drawing beside its card.
5. With yarn of one color, connect each American food to its homeland on the map and stretch it across the Atlantic to a place it spread to. Use the second color for Old World foods and animals.
6. Add a small card for the hidden passengers: smallpox, measles and influenza, with one sentence about what they did.
7. Plan a meal with a parent that uses at least three foods from each side (for example, potato soup with onions, cornbread with butter, and a banana). Eat it and tell the story of where each food came from.

Tips

- Some foods mix both sides: chocolate cake uses cacao from the Americas with wheat and sugar from the Old World.
- Cranberries, blueberries, sunflowers and wild rice are also native to North America if you want more examples.

Check your work

- Every food is on the correct side of the chart with its homeland.
- My map shows the direction each food traveled.
- I included the diseases and can explain why they were so deadly in the Americas.

MAP NOTEBOOK

1. Copy the Columbian Exchange map. Draw small pictures beside each arrow: a potato, an ear of corn, a horse, a stalk of sugarcane.
2. Draw your favorite meal on a plate and label each food “Americas” or “Old World.”
3. Draw a Plains rider on a horse and write one sentence about how horses changed life on the Great Plains.

From history. When the potato first reached Europe in the late 1500s, many people distrusted it. In France, a pharmacist named Antoine-Augustin Parmentier, who had eaten potatoes as a prisoner of war in Prussia, worked for years in the 1770s and 1780s to persuade the French to grow and eat them. Dishes made with potatoes are still called “Parmentier” in French cooking.

WORKED EXAMPLES

Example 1. The potato was first farmed near Lake Titicaca in the Andes at about 16°S . Ireland, where it later became the main food, is at about 53°N . How many degrees of latitude did the potato travel, and how many nautical miles is that north to south?

(Use the map or drawing “Find the Andes and Ireland.” shown earlier in this lesson.)

1. One place is south of the equator and one is north, so add the two latitudes: $16^{\circ} + 53^{\circ} = 69^{\circ}$.
2. Each degree is 60 nautical miles: $69 \times 60 = 4,140$ nautical miles.
3. Change to land miles: $4,140 \times 1.15 \approx 4,760$ miles (about 7,700 km). The real journey by sea was much longer, because ships had to sail around and across the ocean.

Answer: 69° of latitude, or 4,140 nautical miles (about 4,760 miles) north to south.

Example 2. Sort a pepperoni pizza by the Columbian Exchange. The crust is wheat; the sauce is tomatoes; the cheese is from cow's milk; the pepperoni is pork with chili pepper (paprika) in it. Which parts came from the Americas and which from the Old World?

1. Wheat was first farmed in the Middle East: Old World.
2. Tomatoes came from the Americas (Mexico and South America): Americas.
3. Cows were brought from the Old World: Old World.
4. Pigs were brought from the Old World, but chili peppers came from the Americas: both.

Answer: Americas: tomato sauce and the chili pepper in the pepperoni. Old World: wheat crust, cheese from cows, and pork. An "Italian" pizza could not exist without the Columbian Exchange.

PRACTICE

1. **EASY** Name three foods that first grew in the Americas.
2. **EASY** Name three animals that Europeans brought to the Americas.
3. **MEDIUM** Columbus's second voyage left Cádiz on September 25, 1493, and sighted Dominica on November 3. How many days was that?
4. **MEDIUM** The potato blight struck Ireland in 1845. How many years was that after Columbus's first voyage in 1492?
5. **MEDIUM** Look at the map. In which general direction does the arrow travel from the Andes to Europe? In which direction does the arrow from Spain to the Caribbean travel?
(Use the map or drawing "Read the direction of each arrow." shown earlier in this lesson.)
6. **HARD** Tenochtitlan (Mexico City) is at about 99°W. Seville in Spain is at about 6°W. How many degrees of longitude apart are they? Using 15° for each hour, about how many hours apart is their noon?
7. **HARD** In two or three sentences, explain why smallpox and measles killed so many more people in the Americas than in Europe.
8. **CHALLENGE** Sort this Thanksgiving dinner into Americas and Old World: roast turkey, mashed potatoes with butter, green beans, cranberry sauce, and pumpkin pie made with wheat-flour crust and sugar.

COMMON MISTAKES

- Thinking potatoes came from Ireland or tomatoes from Italy. Both are American plants that only reached Europe after 1492.
- Thinking horses were always part of Native American life. There were no horses in the Americas in 1492; Plains nations became great horsemen in the 1600s and 1700s after the Spanish brought them.

- Thinking the diseases were spread on purpose. Almost all were spread by accident, by people who did not know germs existed. The deaths were no less terrible for that.

Make it a game · Cross the Ocean. Lay two blankets on the floor a few steps apart: one is the Americas, the other is the Old World. A parent calls out a food, animal or disease (potato, horse, coffee, turkey, smallpox, chocolate, wheat, cassava). Players must jump from the blanket where it began to the blanket where it traveled. A wrong jump means you sit out one turn. For a bonus point, name a country where that food is eaten every day now.

Scripture. “And God said, Behold, I have given you every herb bearing seed, which is upon the face of all the earth, and every tree, in the which is the fruit of a tree yielding seed; to you it shall be for meat.” (Genesis 1:29, KJV)

God placed the potato in the Andes and wheat in the Middle East, but He gave them to all people. When the two halves of the world met, His gifts were shared more widely than ever. We are called to be thankful stewards of them.

Practice answers

1. Any three: corn (maize), potatoes, tomatoes, beans, squash, pumpkins, peanuts, chili peppers, cacao (chocolate), vanilla, pineapples, cassava, sweet potatoes.
2. Any three: horses, cattle, pigs, sheep, goats, chickens, honeybees.
3. September 25 to 30 is 5 days, plus 31 days of October, plus 3 days of November: $5 + 31 + 3 = 39$ days.
4. $1845 - 1492 = 353$ years.
5. From the Andes to Europe: northeast. From Spain to the Caribbean: southwest (west and a little south).
6. $99^\circ - 6^\circ = 93^\circ$. $93 \div 15 = 6.2$ hours, about 6 hours and 12 minutes. Noon comes to Seville about 6 hours before it comes to Mexico City.
7. People in Europe, Africa and Asia had lived with these diseases for centuries, so many had immunity, and many caught them as children and survived. The peoples of the Americas had never met them, so whole towns fell sick at once, with no immunity and no one healthy to care for the sick.
8. Americas: turkey, potatoes, green beans, cranberries and pumpkin. Old World: butter (from cows), wheat flour and sugar (from sugarcane).

8.4 WHAT MAKES A GOOD EXPLORER?

OBJECTIVES

- Name three marks of a good explorer (truth, courage and humility) and give a real example of each from the Lewis and Clark expedition (1804–1806) or from earlier lessons.
- Contrast honest reporting with false reporting, using the Lewis and Clark journals and Walter Raleigh’s promises of gold in Guiana.
- Plan and write a short essay with a clear claim, three reasons with real examples, and a conclusion.

Warm-up. Hide a small object somewhere in one room. Give a sibling or parent directions to find it, but tell one small untrue thing in your directions (for example, “turn left” when you mean right). Then do it again with completely true directions. Talk about it: what happens to a traveler who follows a map or report with even one lie in it?

Video. Coming soon. The Lewis and Clark expedition (1804–1806): the journals, Sacagawea and York, the vote at the mouth of the Columbia, and Clark’s 1814 map: search Drive Thru History, The History Guy, Library of Congress, Smithsonian and Homeschool Pop (Alternate: explorers).

KEY TERMS

truthfulness

Telling and recording what really happened, even when the truth is disappointing or makes you look small.

humility

Seeing yourself rightly: knowing your limits, giving others credit and being willing to learn and be corrected.

journal

A daily written record. Explorers’ journals record weather, distances, positions, people met and plants and animals seen.

claim

In an essay, the main idea you are trying to show is true.

evidence

Facts and examples that show a claim is true.

CORE IDEAS

The story. On November 24, 1805, a wet and weary band of explorers camped near the mouth of the Columbia River, where it meets the Pacific Ocean. They were the Corps of Discovery, led by Meriwether Lewis and William Clark, who had left the St. Louis area in

May 1804. Winter was coming, and they had to decide where to build a fort. So the captains did something unusual: they asked everyone. Clark wrote down each vote in his journal, including the vote of York, a black man Clark held in slavery, and of Sacagawea, the young Shoshone mother who had come with them. Most chose to cross to the south side of the river, where elk were plentiful. There they built Fort Clatsop and spent the rainy winter.

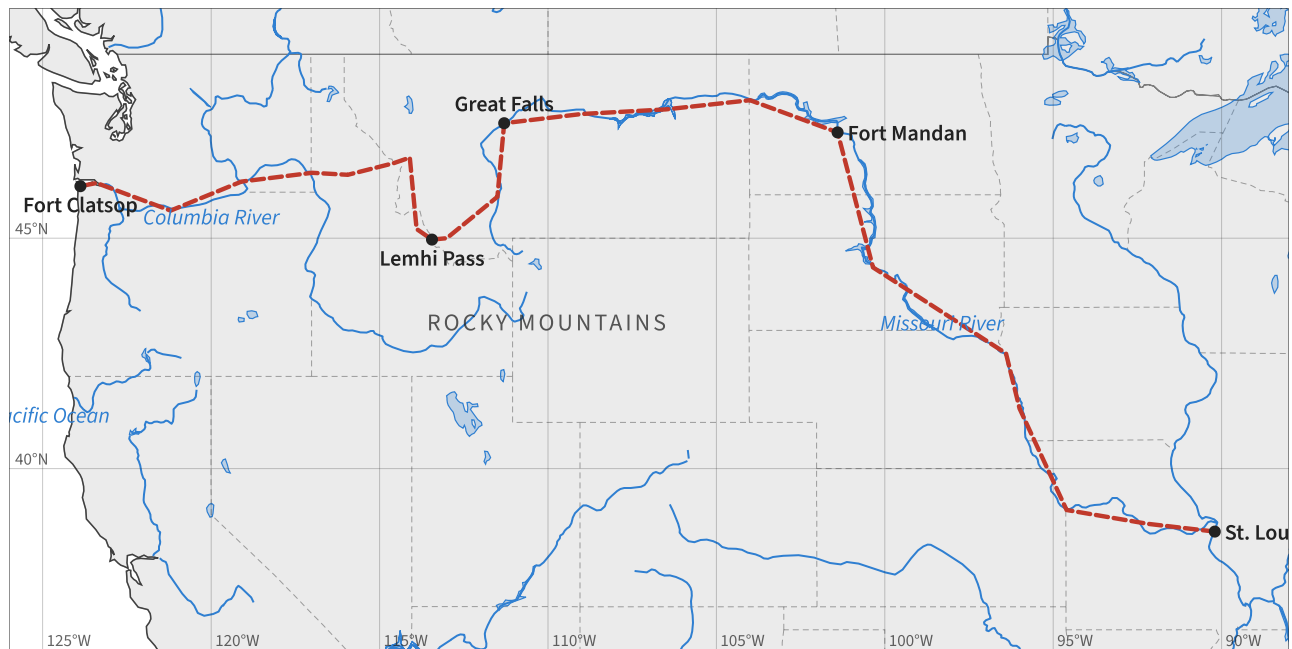
Truth. President Thomas Jefferson had hoped Lewis and Clark would find an easy water route across the continent, with only a short carry over the mountains to the Columbia. On August 12, 1805, Lewis climbed to the top of Lemhi Pass on the Continental Divide, expecting to see a river flowing gently to the Pacific. Instead he saw range after range of snow-capped mountains. The captains reported that disappointing truth. They measured latitude with their instruments, recorded distances, and described more than a hundred plants and animals new to science. Compare Sir Walter Raleigh, who sailed to Guiana in South America in 1595 and wrote a book promising a rich land of gold. There was no such land. When he went back in 1617, the voyage failed, men died, and Raleigh was executed in England in 1618. A false report costs lives; a true report saves them.

Courage. The Corps crossed the Bitterroot Mountains in September 1805 through early snow, so hungry that they killed some of their colts for food. They had already rowed and dragged their boats more than 2,000 miles up the Missouri and carried them around the Great Falls of the Missouri, a portage of about 18 miles over rough, cactus-covered ground. Their stay at the falls lasted nearly a month. In more than two years, only one man died: Sergeant Charles Floyd, probably of a burst appendix, in August 1804. Good leaders are brave, and they also bring their people home.

Humility. The Corps would have failed without help. Sacagawea recognized landmarks of her homeland, and when they met the Shoshone, their chief turned out to be her own brother, Cameahwait, who traded them the horses they needed to cross the mountains. Later the Nez Perce fed the starving men and kept their horses safe through the winter. Lewis and Clark wrote this help down. Humility also means admitting the wrongs within your own story: York did the same hard work and cast his vote, yet Clark did not free him until years after they came home. Columbus, by contrast, never admitted he had not reached Asia. A proud explorer hides what he got wrong; a humble one learns.

The big idea. In this unit you have seen great courage and skill, real wrongs, and an exchange that brought both blessing and grief. Micah sums up what God asks of every person, explorer or not: to do justly, to love mercy, and to walk humbly with God. A good explorer tells the truth, faces danger bravely, and stays humble enough to give others credit and admit mistakes.

Writing your essay. Your essay will answer the question “What makes a good explorer?” in five short paragraphs. Begin with a **claim**. Give three reasons, each with real **evidence**: a person, a place and a date. End with a conclusion that says why it matters for us, who explore our own world every day. Use the map of the Lewis and Clark route to find your examples.



The route of the Corps of Discovery to the Pacific, 1804-1805.

PICTURE STUDY



The Boyhood of Raleigh, John Everett Millais, 1870 · Oil on canvas · Tate Britain, London

John Everett Millais painted this scene on the coast of Devon in southwest England, using his own two sons as the models for the boys. It imagines young Walter Raleigh, who grew up in Devon in the 1550s and 1560s, listening to an old sailor's tales of distant lands. The sailor points out to sea, toward the unknown.

The painting is about the wonder that makes people want to explore. But remember what Raleigh grew up to do: he became a brave sailor and soldier, and also wrote a book of false

promises about gold in Guiana. Wonder and courage are good gifts, and they need truth and humility to guide them.

Look closely

- Find the sailor's pointing hand. Follow it with your eyes. Where is it leading?
- Look at the two boys. Which one seems more caught up in the story? How can you tell?
- Look at the sailor's clothes, skin and face. What clues tell you he has traveled far?
- Look at the sea in the background. How much of it can you see?

Talk about it

1. Have you ever heard a story that made you want to go somewhere far away? What was it?
2. If you could give young Raleigh one piece of advice about what makes a good explorer, what would you say?
3. Is the sailor's story necessarily true? How would a good listener find out?

PROJECT: MY ESSAY: WHAT MAKES A GOOD EXPLORER?

You will write a five-paragraph essay answering the question "What makes a good explorer?" using real examples from this course. You will plan it on paper first, write it, read it aloud, and illustrate it with a small map.

You will need

- Lined paper and pencil, or a computer
- Your map notebook from this course
- Five index cards
- Colored pencils for a small map

Steps

1. Write the question at the top of a page. On the first index card, write your claim in one sentence, for example: "A good explorer is truthful, courageous and humble."
2. On three more cards, write one quality each. Under each, write one real example with a person, a place and a date. Choose from any unit: Lewis and Clark, Columbus, Elcano, Captain Cook, Livingstone, Amundsen, Shackleton, Hillary and Tenzing, or another you studied.
3. On the last card, write one example of an explorer who lacked one of these qualities and what it cost (for example, Raleigh's false report of gold, or Columbus's harsh rule as governor).
4. Write paragraph 1: introduce the question and state your claim.
5. Write paragraphs 2, 3 and 4: one quality in each, with your example and one sentence on why that quality matters.

6. Write paragraph 5: a conclusion. Include your counterexample and a sentence on how you can be truthful, brave and humble in your own life.
7. Read your essay aloud to your family. Then draw a small map in the corner showing where one of your examples took place.

Tips

- Every reason needs a real example. “Lewis reported the mountains honestly in August 1805” is stronger than “explorers should be honest.”
- Use plain, true words. If you are not sure of a date or number, check it or leave it out. That is the truthfulness you are writing about.

Check your work

- My essay has a claim, three reasons with real examples, and a conclusion.
- Every example names a real person, place and date.
- I included one honest counterexample.

MAP NOTEBOOK

1. Copy the map of the Lewis and Clark route. Label St. Louis, Fort Mandan, the Great Falls, Lemhi Pass and Fort Clatsop, and write the latitude of St. Louis and Fort Clatsop in degrees and minutes.
2. Make three boxes labeled Truth, Courage and Humility. In each, draw a small picture of a real moment from this course that shows that quality.
3. Copy one page from a real explorer’s journal into your notebook in your own words: write today’s weather, the direction you walked today, and one plant or animal you saw, the way Lewis and Clark did.

From history. In 1814 William Clark’s great map of the West was printed with the first published history of the expedition. It showed the Rocky Mountains as a wide band of ranges, not a single ridge, and it corrected many guesses on earlier maps. For decades, mapmakers copied it. On the way home, on July 25, 1806, Clark carved his name and the date into a sandstone pillar beside the Yellowstone River in what is now Montana. The carving, at Pompeys Pillar, can still be seen today.

WORKED EXAMPLES

Example 1. St. Louis is at about $38^{\circ}37'N$. Fort Clatsop is at about $46^{\circ}08'N$. How far apart are they in latitude, and how many nautical miles is that north to south?

(Use the map or drawing “Compare the latitudes of St. Louis and Fort Clatsop.” shown earlier in this lesson.)

1. Set up the subtraction: $46^{\circ}08' - 38^{\circ}37'$. We cannot take $37'$ from $8'$, so borrow 1 degree, which is 60 minutes: $46^{\circ}08'$ becomes $45^{\circ}68'$.
2. Minutes: $68' - 37' = 31'$. Degrees: $45^{\circ} - 38^{\circ} = 7^{\circ}$. Difference: $7^{\circ}31'$.
3. Change to nautical miles: $7 \times 60 = 420$, plus 31 = 451 nautical miles.
4. In land miles: $451 \times 1.15 \approx 520$ miles (about 840 km).

Answer: $7^{\circ}31'$ of latitude, or 451 nautical miles (about 520 miles) north to south. Of course the Corps traveled much farther, because most of their journey ran east to west.

Example 2. St. Louis is at about $90^{\circ}12'W$ and Fort Clatsop is at about $123^{\circ}53'W$. How many degrees of longitude apart are they? How much later does local noon come at Fort Clatsop than at St. Louis? (Remember from Unit 3: the sun moves 15° each hour, which is 1° every 4 minutes.)

(Use the map or drawing “St. Louis in the east and Fort Clatsop in the west.” shown earlier in this lesson.)

1. Subtract: $123^{\circ}53' - 90^{\circ}12'$. Minutes: $53' - 12' = 41'$. Degrees: $123^{\circ} - 90^{\circ} = 33^{\circ}$. Difference: $33^{\circ}41'$, which is a little less than 34° .
2. Each degree takes 4 minutes of time: $33 \times 4 = 132$ minutes for the whole degrees.
3. 41 minutes of arc is about two-thirds of a degree, which is about 2.7 more minutes of time. Total about 135 minutes.
4. 135 minutes = 2 hours 15 minutes.

Answer: About $33^{\circ}41'$ of longitude. Local noon at Fort Clatsop comes about 2 hours and 15 minutes after noon at St. Louis.

PRACTICE

1. **EASY** Name the three marks of a good explorer in this lesson and give a one-sentence meaning of each.
2. **EASY** On what date did the Corps of Discovery vote on where to spend the winter, and which two people were included whose votes would not usually have been counted in 1805?
3. **MEDIUM** The expedition set out on May 14, 1804, and returned to St. Louis on September 23, 1806. How long were they gone, in years, months and days?

4. **MEDIUM** Look at the map. In which general direction did the expedition travel from St. Louis to Fort Mandan? In which direction from Lemhi Pass to Fort Clatsop?
(Use the map or drawing “Read the directions between points on the route.” shown earlier in this lesson.)
5. **MEDIUM** Fort Mandan was at about 47°18'N. St. Louis is at about 38°37'N. How many degrees and minutes north of St. Louis was Fort Mandan, and how many nautical miles is that?
6. **HARD** In November 1806 Zebulon Pike tried to climb the great peak in Colorado now named for him and failed; he wrote that he believed no one could ever reach its top. A party with Edwin James climbed it in July 1820. Pikes Peak is 14,115 feet high. About how many miles is that? What does Pike’s mistake teach about humility?
7. **HARD** Walter Raleigh wrote a book in 1596 promising a land rich in gold in Guiana. Which quality of a good explorer did that report lack? What happened when he went back in 1617?
8. **CHALLENGE** Write the first paragraph of your essay “What Makes a Good Explorer?” It must state a clear claim and name the three qualities you will write about.

COMMON MISTAKES

- Writing reasons without evidence. Every reason in your essay needs a real person, place and date.
- Thinking a good explorer must be perfect. Lewis and Clark made mistakes and Clark held York in slavery; we can honor real virtues and still name real wrongs.
- Confusing pride with courage. Bravery faces danger for a good purpose; pride takes needless risks, hides mistakes and refuses help.

Make it a game · Truth, Courage or Humility?. A parent reads a real moment from this course (for example, “Lewis reports the mountains beyond Lemhi Pass,” “Elcano brings the *Victoria* home,” “The captains record the Nez Perce’s help,” “Raleigh promises gold that is not there”). Players hold up one of four cards: Truth, Courage, Humility, or Missing! if the moment shows a quality was lacking. Explain your card to earn the point. Play until each player has given ten answers.

Scripture. “He hath shewed thee, O man, what is good; and what doth the LORD require of thee, but to do justly, and to love mercy, and to walk humbly with thy God?” (Micah 6:8, KJV)

This verse is a good measure for judging any explorer, and for judging ourselves. Doing justly includes telling the truth and treating others rightly; walking humbly means admitting that we need God and other people.

Practice answers

1. Truth: recording and reporting what really happened. Courage: going on in real danger and bringing your people home. Humility: knowing your limits, giving others credit and admitting

mistakes.

2. November 24, 1805. York, a black man held in slavery by Clark, and Sacagawea, a Shoshone woman.
3. May 14, 1804 to May 14, 1806 is 2 years; to September 14, 1806 is 4 more months; to September 23 is 9 more days. Total: 2 years, 4 months and 9 days.
4. From St. Louis to Fort Mandan: northwest. From Lemhi Pass to Fort Clatsop: west (a little north of west, since Fort Clatsop is about 1° farther north but about 10° farther west).
5. $47^\circ 18'$ becomes $46^\circ 78'$; $46^\circ 78' - 38^\circ 37' = 8^\circ 41'$. That is $8 \times 60 + 41 = 521$ nautical miles.
6. $14,115 \div 5,280 \approx 2.7$ miles (about 2 and two-thirds miles). It teaches that we should not be too sure that what we could not do can never be done; a humble explorer admits his limits without claiming they are everyone's limits.
7. It lacked truthfulness. The gold he promised did not exist; his 1617 expedition failed, men died, and Raleigh was executed in England in 1618.
8. Answers will vary. A good paragraph asks the question, states a claim such as "A good explorer is truthful, courageous and humble," and briefly previews a real example for each, for example Lewis's honest report from Lemhi Pass, Elcano bringing the *Victoria* home, and the captains recording the help they received from Sacagawea and the Nez Perce.

UNIT 8 REVIEW

Answer each question. Show your work for calculations and use complete sentences for explanations. Use 60 nautical miles for one degree of latitude and 15 degrees of longitude for one hour of time. The review is worth 50 points.

1. (4 pts) Why did Columbus sail south to the Canary Islands before turning west in 1492, and why did he sail north toward the Azores to come home?
2. (5 pts) Columbus's fleet sailed about 3,100 nautical miles from Gomera to San Salvador in 36 days. About how many nautical miles did they sail each day, and what was their speed in knots?
3. (4 pts) Name two true things Columbus got wrong or was not first to do, and one thing he truly did first.
4. (4 pts) Who brought the first ship all the way around the world, what was its name, and in what year did it return?
5. (5 pts) Describe in plain words two wrongs Columbus did as governor of Hispaniola, and tell what happened to him in 1500.
6. (5 pts) Where and when did the first large sale of captured Africans in Portugal take place? Lagos is at about 37°N and Cape Bojador at about 26°N; how many nautical miles south of Lagos is Cape Bojador?
7. (5 pts) Name one person living at the time who spoke against the cruel treatment of native peoples, and explain why this shows these wrongs were not judged wrong only by modern standards.
8. (6 pts) Make a two-column list: three foods or animals that went from the Americas to the Old World, and three that went from the Old World to the Americas. Then name one disease that crossed the ocean and explain why it was so deadly in the Americas.
9. (5 pts) The potato was first farmed near Lake Titicaca at about 16°S and became the main food of Ireland at about 53°N. How many degrees of latitude apart are these places, and how many nautical miles north to south? What happened in Ireland in 1845?
10. (7 pts) St. Louis is at about 38°37'N and 90°12'W; Fort Clatsop is at about 46°08'N and 123°53'W. (a) How many nautical miles apart are they north to south? (b) About how much later is local noon at Fort Clatsop? (c) Give one real example of truth, courage or humility from the Lewis and Clark expedition.

UNIT PROJECT: JUDGING EXPLORERS HONESTLY: MY MAP, CHART AND ESSAY

Make a large map of the Atlantic world that shows Columbus's wind loop of 1492-1493 and the plants and animals that crossed the ocean after it, with arrows in two colors and small drawings of each food and animal at its homeland. Beside the map, mount your Columbian Exchange chart with real foods and your "Two Columns of Truth" poster on one explorer.

Finish with your five-paragraph essay, "What Makes a Good Explorer?", written neatly or typed, with a claim, three reasons with real examples from this course, an honest

counterexample, and a conclusion. Read the essay aloud to your family as you present your map.

- **Accuracy:** Places, routes, latitudes, dates and the homelands of foods and animals are correct and clearly labeled.
- **Honesty:** The chart and poster give real credit for courage and skill and name real wrongs plainly, each with a date, place and source.
- **Essay:** The essay has a clear claim, three reasons each backed by a real person, place and date, a counterexample, and a thoughtful conclusion.
- **Care:** The map, chart and essay are neat, colorful, complete and easy to read.

Answer key

1. Near the Canaries the trade winds blow steadily from the northeast and carry ships west. Farther north, near the Azores, the westerlies blow toward Europe and carry ships home. The two make a clockwise loop.
2. $3,100 \div 36 \approx 86$ nautical miles a day. $86 \div 24 \approx 3.6$ knots.
3. Any two: he did not prove the earth was round (educated people already knew it); he badly underestimated the size of the earth and the distance to Asia; he believed to his death that he had reached Asia; he was not the first to reach the Americas (native peoples lived there, and Norse sailors reached Newfoundland about 1000). First: he made a round-trip crossing that connected Europe and the Americas for good.
4. Juan Sebastián Elcano brought the *Victoria* home to Spain in 1522, after Magellan was killed in the Philippines in 1521.
5. Any two: he forced the Taíno to bring gold dust as tribute every three months and had those who failed punished harshly; he shipped about 500 Taíno to Spain to be sold as slaves in 1495; he ruled settlers with cruel punishments. In 1500 Francisco de Bobadilla arrested him and sent him to Spain in chains, and he was never allowed to govern again.
6. At Lagos, Portugal, in 1444. $37^\circ - 26^\circ = 11^\circ$, and $11 \times 60 = 660$ nautical miles.
7. Antonio de Montesinos (preached on Hispaniola in 1511), Bartolomé de las Casas (gave up his laborers in 1514 and defended native peoples for fifty years) or Queen Isabella (ordered sold Taíno freed). People at the time, guided by the Bible's teaching that all nations are of one blood and that man-stealing is wrong, called these things sins, so the standard was known then.
8. Americas to Old World (any three): corn, potatoes, tomatoes, beans, squash, peanuts, chili peppers, cacao, turkeys, cassava. Old World to Americas (any three): horses, cattle, pigs, sheep, chickens, wheat, rice, sugarcane, coffee, bananas. Disease: smallpox, measles or influenza; the peoples of the Americas had never met it and had no immunity.
9. $16^\circ + 53^\circ = 69^\circ$, and $69 \times 60 = 4,140$ nautical miles. In 1845 a blight rotted the potato crop, and in the famine that followed about a million people died and about a million more emigrated.
10. (a) $46^\circ 08' - 38^\circ 37' = 7^\circ 31'$, which is 451 nautical miles. (b) $123^\circ 53' - 90^\circ 12' = 33^\circ 41'$; at 4 minutes per degree that is about 135 minutes, or about 2 hours 15 minutes later. (c) Any one: Lewis honestly reported the endless mountains he saw from Lemhi Pass on August 12, 1805 (truth); the Corps crossed the snowy Bitterroots in September 1805 (courage); the captains recorded the help of Sacagawea, Cameahwait and the Nez Perce, and let York and Sacagawea vote on November 24, 1805 (humility).

BONUS: MAP LAB

All year you have sailed with the Portuguese down the coast of Africa, measured the North Star with a quadrant, followed John Harrison's clocks to sea, peeled a globe with Mercator, charted coasts with Captain Cook, walked with the missionaries and raced to the poles. Now it is time to play with what you have learned. The Map Lab is a bonus unit of four lighter lessons full of games, drawing and outdoor adventure. Each one still begins with a real story: the *Titanic's* distress call in 1912, the *Victoria's* return in 1522 after the first voyage around the world, Olaus Magnus's sea-monster map of 1539, and the first orienteering races in Scandinavia.

You will plot ships by latitude and longitude in degrees and minutes, build and play a deck of honest explorer cards, draw an old-style map with a compass rose, rhumb lines and a cartouche, and run an orienteering course in a park with a compass and your own pace count. These lessons may be done in any order, as a break during the year or as a celebration at the end. Through them all runs the series verse: God "hath made of one blood all nations of men for to dwell on all the face of the earth, and hath determined the times before appointed, and the bounds of their habitation" (Acts 17:26).

BEFORE YOU BEGIN

- Can read latitude and longitude and knows that 1 minute of latitude is 1 nautical mile (Units 2-3)
- Knows dead reckoning: direction, speed and time (Lesson 2.3)
- Knows the main explorers and missionaries of Units 1 and 5-8
- Can use a protractor to measure angles and a ruler with a map scale

MASTERY CHECKLIST

- I can plot a position given in degrees and minutes, such as 41°46' N, 50°14' W, on a chart.
- I can change a difference in latitude into nautical miles.
- I can make an explorer card with true, checkable statistics and an honest truth box.
- I can draw a 16-point compass rose and give the bearing of each main point in degrees.
- I can draw an old-style map with a cartouche and a working scale.
- I can follow a compass bearing, find a back bearing and use my pace count to walk a set distance.

OPTIONAL BOOKS AND RESOURCES

- **Library of Congress Maps Collection** (<https://www.loc.gov/maps/>): Free. Zoom in on old maps with compass roses, cartouches and sea creatures for ideas for your old-style map (Lesson 9.3), and on Waldseemüller's 1507 map from Unit 4.

- **Orienteering USA** (<https://orienteeringusa.org/>): Free to browse. Find a local orienteering club, beginner events and permanent courses in parks near you (Lesson 9.4). A parent should look first and choose an event.

9.1 FIND THE SHIP

OBJECTIVES

- Read and write a position at sea in degrees and minutes of latitude and longitude, such as $41^{\circ}46'$ N, $50^{\circ}14'$ W.
- Plot ships on a latitude and longitude grid, remembering that west longitude grows toward the left on a map.
- Tell how the Titanic's distress call gave rescuers a position, and why the wreck was found a few miles away from it.

Warm-up. Lay a sheet of graph paper on the table. Number the lines across the bottom 1 to 10 and the lines up the side 1 to 10. Hide a coin on one crossing and give a partner two numbers, “across 7, up 3,” to find it. Then switch. Two numbers are enough to find any spot on the sheet. Sailors do the same thing on the whole round earth.

Watch. *Titanic: The Night the “Unsinkable” Ship Sank* (The Photographed Past, 9:23). <https://www.youtube.com/watch?v=mbFQMZd90xs>

After the story: watch for the moment the distress call goes out and the Carpathia races to pick up the lifeboats.

Note: Captions were not available to check; preview it first. It is about the sinking, including the many deaths and the class divisions aboard, and it comes from a little-known channel whose narration may be computer-generated. Based on the description, it may not cover how Boxhall worked out the position, the coordinates $41^{\circ}46'$ N, $50^{\circ}14'$ W, or the 1985 discovery of the wreck.

Backup video. *How to read Latitude and Longitude Coordinates* (Mr Gedge's Geography Channel, 4:07). <https://www.youtube.com/watch?v=lUMlmRzkuuY>

Before the project: watch how latitude and longitude lines work so you can plot the Titanic's position on your map. Note: Captions were not available to check; preview it first. The teacher is British, and the description says a version with better sound exists. The description lists the main lines and hemispheres but does not mention degrees and minutes, which the lesson uses.

KEY TERMS

latitude

How far north or south of the equator a place is, measured in degrees from 0° at the equator to 90° at the poles.

longitude

How far east or west of the prime meridian at Greenwich a place is, measured in degrees from 0° to 180° .

minute (of arc)

One sixtieth of a degree. $41^{\circ}30'$ means 41 and a half degrees. The mark $'$ stands for minutes.

position

The exact spot of a ship or place, given as a latitude and a longitude together.

distress call

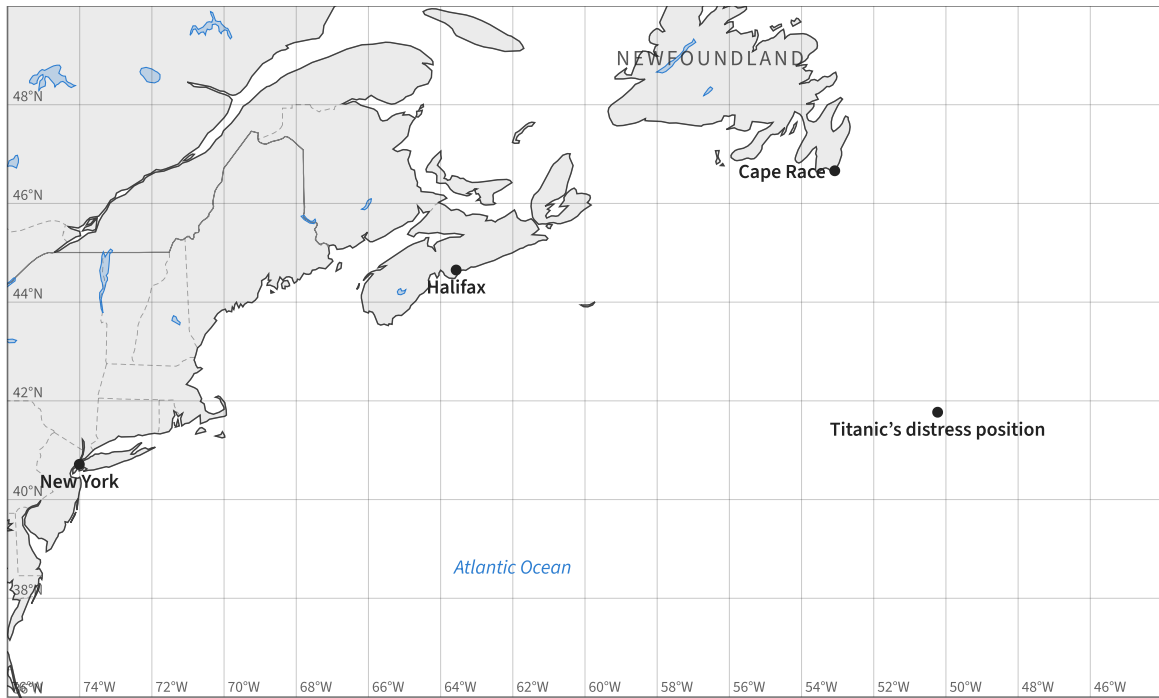
An urgent radio message from a ship in danger, giving its position so others can come to help.

CORE IDEAS

The story. Late on the night of April 14, 1912, the great liner *Titanic* struck an iceberg in the North Atlantic on her first voyage, from Southampton to New York. Fourth Officer Joseph Boxhall quickly worked out the ship's position by dead reckoning, from her speed, her heading and the hours since the last star sight. The wireless operators tapped it out again and again: **$41^{\circ}46' \text{ N}$, $50^{\circ}14' \text{ W}$** . Far away, Captain Arthur Rostron of the *Carpathia* heard the call, turned his ship around and drove her through the dark, dodging icebergs, toward those numbers. He arrived about $3\frac{1}{2}$ hours later, after the *Titanic* had sunk, and took more than 700 survivors out of the lifeboats. Two numbers on a radio had saved their lives.

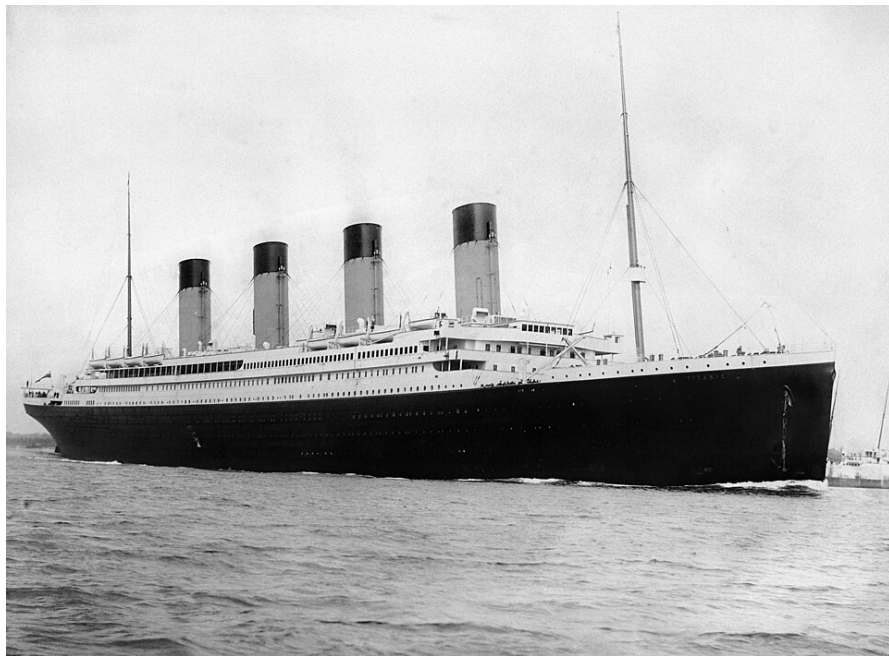
How it works. A position is a pair: latitude first, then longitude. Each degree is split into 60 **minutes**, so $41^{\circ}46' \text{ N}$ means 41 degrees and 46 sixtieths of the way to 42° , about three-quarters of the way. To plot it, find 41° N on the side of the chart, move up three-quarters of the way to 42° , then find 50° W along the bottom and move about a quarter of the way toward 51° W . Careful! In the Western Hemisphere, west longitude numbers grow as you go *left* (west) on the map, so 51° W is to the left of 50° W . Where your two lines cross, there is the ship. And remember from Unit 2: one minute of latitude is one **nautical mile**, so 60 minutes, or 1 degree, is 60 nautical miles north or south.

On the map. Boxhall did well in a terrible hour, but dead reckoning is never perfect. On September 1, 1985, a team led by Robert Ballard of the United States and Jean-Louis Michel of France found the wreck on the ocean floor, about $2\frac{1}{2}$ miles (4 km) down, near **$41^{\circ}43' \text{ N}$, $49^{\circ}56' \text{ W}$** . That is about 13 nautical miles east-southeast of the distress position. The lifeboats had drifted near the true spot, which is how the *Carpathia* still found them at dawn. Today ships carry GPS, which can give a position within a few yards, but every officer still learns to plot by hand, in case the electronics fail. In this lab you will be the officer on watch.



The Titanic's distress position, 41°46' N, 50°14' W. Cape Race on Newfoundland was the wireless station that heard her calls.

PICTURE STUDY



*RMS Titanic Leaving Southampton, Francis Godolphin Osbourne Stuart (photographer), April 10, 1912 ·
Black-and-white photograph · Widely reproduced; prints are held in many collections*

This photograph shows the *Titanic* leaving Southampton, England, at the start of her first and only voyage. She was one of the largest moving objects people had ever built, about 882 feet long, nearly three football fields. Many people believed she was too big and too well made to sink.

Look at her as a navigator would. A ship this big still needed two numbers, a latitude and a longitude, to tell the world where she was. Five days after this picture was taken, those two numbers were the most important thing on board.

Look closely

- Count the funnels. (Only three of the four sent out smoke; the fourth helped air the ship.)
- Find the tall masts at the front and back. Wires strung between them were the wireless aerial that sent out her distress call.
- Look for the lifeboats along the top deck. Are there many or few for a ship this size?
- Compare the size of the ship with the small boats or people near it.

Talk about it

1. Why was the ship's wireless radio so important on the night of April 14?
2. Why do you think people trusted the ship so much? Is it wise to trust anything we build that much?
3. If you had been Captain Rostron, what would you have needed to know to find the lifeboats?

PROJECT: FIND THE SHIP: A CHART-PLOTTING GAME

You will make your own sea chart on graph paper with real latitude and longitude lines, then play a rescue game. One player hides ships and sends "distress calls" in degrees and minutes. The other plots the calls and sends the rescue ship. Fast, careful plotting wins.

You will need

- Two sheets of graph paper (four or five squares to the inch works well)
- A ruler and a sharp pencil
- Red and blue colored pencils
- A file folder or book to stand up as a screen between players
- Two small coins or buttons per player as "ships"
- Your map notebook

Steps

1. On each sheet, draw a chart from 40° N to 46° N and from 60° W to 50° W, like the grid in this lesson. Let 6 squares equal 1 degree, so each square is 10 minutes.
2. Label the latitudes up the left side (40° N at the bottom) and the longitudes across the bottom, with 60° W on the *left* and 50° W on the *right*.
3. Draw a small compass rose and write "North Atlantic" in a corner.
4. Behind the screen, the first player marks three "ships in distress" in red on their own chart, each on a crossing of lines or on a 10-minute mark, and writes down each position.

5. The first player calls out one position, for example “Mayday! 43°20′ North, 55°40′ West.” The rescuer plots it in blue and says where it is: “A third of the way from 43° up to 44°, and two-thirds of the way from 55° W toward 56° W, just *east* of the 56° line.”
6. Lift the screen and compare. If the rescuer’s dot is within one square of the ship, the rescuer scores a point.
7. Switch roles. After three rounds each, write in your notebook one tip that helps you plot quickly and correctly.

Tips

- Always plot latitude first (up and down), then longitude (left and right).
- Say the minutes as a fraction: 30′ is half, 20′ is a third, 40′ is two-thirds, 15′ is a quarter, 45′ is three-quarters.
- Remember that in the west, bigger longitude numbers are farther left.

Check your work

- I can write a position in degrees and minutes with N or S and E or W.
- I can plot a position to within one square on my chart.
- I can explain why 51° W is to the left of 50° W on a map.

MAP NOTEBOOK

1. Copy the Titanic map into your notebook. Mark the distress position with a red X and the wreck position, 41°43′ N, 49°56′ W, with a small black ship.
2. Make a fraction ladder: write 0′, 10′, 15′, 20′, 30′, 40′, 45′, 50′ and 60′ beside a line from one degree to the next, with the fraction of a degree beside each one.
3. Find your own town’s latitude and longitude in an atlas and write it in degrees and minutes at the top of a new page titled “Where I Am.”

From history. The loss of the *Titanic* changed the rules of the sea. In 1914 the first International Convention for the Safety of Life at Sea called for enough lifeboats for everyone on board and steady radio watches, and that same year the International Ice Patrol began. Run by the U.S. Coast Guard, it still watches for icebergs in the North Atlantic each spring and broadcasts their positions, in latitude and longitude, to every ship nearby.

WORKED EXAMPLES

Example 1. Plot the Titanic's distress position, $41^{\circ}46'$ N, $50^{\circ}14'$ W, on a chart with lines every degree. Describe where the dot goes.

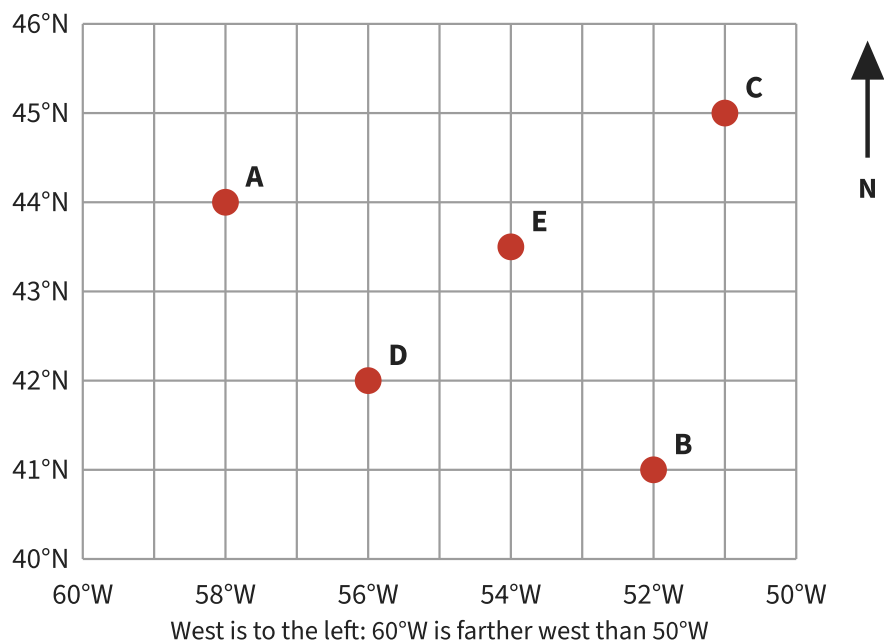
(Use the map or drawing "Check your plot against the map." shown earlier in this lesson.)

1. Latitude first. $41^{\circ}46'$ N is between 41° N and 42° N. 46 minutes out of 60 is a little more than 45 out of 60, or about three-quarters of the way up from 41° toward 42° .
2. Longitude next. $50^{\circ}14'$ W is between 50° W and 51° W. 14 minutes is a little less than 15 out of 60, or about a quarter of the way.
3. Which way? West longitudes grow toward the left, so the dot goes about a quarter of the way from the 50° W line toward the 51° W line, that is, a little *left* of 50° W.
4. Check on the map: the point lies in the open Atlantic, south of Newfoundland and east of Nova Scotia, on the route between England and New York.

Answer: The dot goes about three-quarters of the way from 41° N to 42° N and about a quarter of the way west (left) from 50° W toward 51° W, in the open ocean south of Newfoundland.

PRACTICE

1. **EASY** Look at the ship grid. Which ship is at 41° N, 52° W? Which ship is at 44° N, 58° W?



Five ships on a North Atlantic grid.

2. **MEDIUM** On the ship grid, write the positions of ship D and ship E in degrees and minutes. Which ship is farthest north, and which is farthest west?

(Use the map or drawing “Read each ship’s latitude first, then its longitude.” shown earlier in this lesson.)

3. **MEDIUM** The Titanic’s distress call gave $41^{\circ}46'$ N. The wreck lies at about $41^{\circ}43'$ N. How many minutes of latitude apart are they? How many nautical miles is that, north to south?
4. **HARD** The Carpathia was about 58 nautical miles from the Titanic’s position and arrived about $3\frac{1}{2}$ hours after turning around. About how fast did she go, in knots (nautical miles per hour)?
5. **CHALLENGE** In two or three sentences, explain why the Titanic’s wreck was not found exactly at the position in the distress call.

COMMON MISTAKES

- Plotting longitude first. Sailors always give and plot latitude first, then longitude.
- Moving the wrong way for west longitude. In the Western Hemisphere, 51° W is to the left of 50° W, not to the right.
- Treating minutes like decimals. $41^{\circ}30'$ is $41\frac{1}{2}$ degrees, not 41.3 degrees, because a degree has 60 minutes, not 100.

Make it a game • Mayday Relay. One player is the radio operator and reads a distress call from a card, such as “Mayday! $44^{\circ}30'$ North, $53^{\circ}20'$ West.” Two rescuers race to plot it on their charts. The first to plot it within one square and say “Rescue ship on the way!” wins a point. For a harder round, the operator gives the position once only, so rescuers must listen and write it down correctly, just as Captain Rostron’s wireless operator did. Play to five points.

Scripture. “If I take the wings of the morning, and dwell in the uttermost parts of the sea; Even there shall thy hand lead me, and thy right hand shall hold me.” (Psalm 139:9–10, KJV)

A navigator works hard to know a ship’s position, and sometimes gets it a little wrong. God never does. No one is ever lost to Him, even in the uttermost parts of the sea.

Practice answers

1. Ship B is at 41° N, 52° W. Ship A is at 44° N, 58° W.
2. D is at 42° N, 56° W. E is at $43^{\circ}30'$ N, 54° W (halfway between 43° and 44°). Ship C (45° N) is farthest north. Ship A (58° W) is farthest west.
3. $46' - 43' = 3$ minutes. One minute of latitude is one nautical mile, so they are about 3 nautical miles apart north to south. (The wreck is south of the distress position.)
4. $58 \div 3.5 \approx 16.6$, so about 17 knots. Captain Rostron pushed the ship faster than her usual top speed of about 14 knots.
5. Fourth Officer Boxhall worked out the position by dead reckoning from speed, heading and time, which always has small errors, and there was no time to check it by the stars. The ship

was really about 13 nautical miles east-southeast of where he figured. A small error in speed or time adds up over many hours of sailing.

9.2 EXPLORER CARDS

OBJECTIVES

- Make a deck of explorer, navigator and missionary cards with true dates, places, numbers and an honest “truth box.”
- Compare explorers by checkable numbers such as year and latitude reached, and change a difference in latitude into nautical miles.
- Tell the story of the first voyage around the world and explain why both Magellan and Elcano deserve a card.

Warm-up. Without looking anything up, write down the names of as many explorers, navigators and missionaries as you can remember from this year in 3 minutes. Next to each, write one thing they did and, if you can, the year. Circle the one you think was bravest. Keep the list: these are the first cards in your deck.

Video. Coming soon. Magellan and Elcano’s voyage around the world (1519–1522) and quick reviews of the great explorers and missionaries of this course. Search The History Guy, Drive Thru History, Memoria Press, Smithsonian, Homeschool Pop (Alternate: explorers), Torchlighters (candidate, needs vetting) for missionaries.

KEY TERMS

circumnavigation

A voyage all the way around the world.

expedition

A journey made by a group of people for a special purpose, such as exploring, mapping or carrying the gospel.

sponsor

A king, company or society that pays for an expedition, as Prince Henry paid for the Portuguese voyages.

primary source

A record written or made at the time by someone who was there, such as a ship’s log, a journal or a letter home.

statistic

A fact given as a number, such as a year, a latitude or a number of days, that can be checked and compared.

CORE IDEAS

The story. On September 20, 1519, five Spanish ships with about 270 men sailed from Sanlúcar de Barrameda in Spain under the Portuguese captain Ferdinand Magellan. They were looking for a way west to the Spice Islands. They found a twisting strait at the tip of

South America, still called the Strait of Magellan, and crossed the whole Pacific, starving on the way. In the Philippines, Magellan tried to force the chief Lapulapu of Mactan to submit to Spain, and on April 27, 1521, he was killed in the fighting on the beach. The Basque sailor Juan Sebastián Elcano took command of the last good ship, the *Victoria*, loaded her with cloves and sailed home around Africa. On September 6, 1522, the *Victoria* came back to Sanlúcar with only 18 of the men who had set out. They were the first people known to have sailed all the way around the world.

How it works. Who should get the card for the first voyage around the world? Magellan planned it and led it across the Pacific, but he died halfway. Elcano finished it, but he had joined a mutiny against Magellan in Patagonia and had been spared. A good explorer card tells the truth about both. In this lab every card has three parts. The **statistics** are numbers you can check: the year, the latitude reached, the days or miles of the journey. The **tool** is what made the journey possible: a caravel, an astrolabe, a chronometer, skis and dogs, oxygen bottles, or a Bible translated into a new language. The **truth box** gives one great deed and, where it belongs, one real wrong, told plainly, like the slave trade that began on the African coast under Prince Henry's sponsorship or Columbus's harsh rule of Hispaniola.

The big idea. Numbers let you compare explorers fairly. Captain Cook reached 71°10' S in January 1774, farther south than anyone before him. Amundsen reached 90° S, the South Pole itself, in 1911. Because 1 degree of latitude is 60 nautical miles, you can turn their latitudes into real distances and see how much farther Amundsen went. But numbers are not the whole story. Hudson Taylor and Mary Slessor never set a latitude record, yet they walked into places few outsiders had mapped, learned the languages and stayed for life. When you score courage and skill on your cards, you are doing what Unit 8 taught: judging by the standard of truth, giving honor where it is due and naming wrongs without excuse.

ROALD AMUNDSEN

Norway · South Pole Expedition

Draw him here,
with skis and sled dogs

Year	1911
Farthest latitude	90° S
Days to the Pole	55
Courage (1 to 10)	___
Skill (1 to 10)	___
Tool: skis and sled dogs	

TRUTH BOX
First to the South Pole,
December 14, 1911. All five
men of his polar team came home.

A sample Explorer Card. The statistics must be true and checkable; you fill in courage and skill yourself and be ready to defend your score.

PICTURE STUDY



Maris Pacifici (Map of the Pacific Ocean), Abraham Ortelius, 1589 · Hand-colored copper engraving · Published in Antwerp and added to later editions of Ortelius's atlas, *Theatrum Orbis Terrarum*; many copies survive in map libraries

Abraham Ortelius of Antwerp made the first printed atlas of the world in 1570. In 1589 he printed this map, the first printed map made just for the Pacific Ocean. In the middle of the sea he drew a great ship: the *Victoria*, the one ship of Magellan's five that came home.

Look how wide Ortelius made the ocean, and how much was still guesswork. The Pacific was the largest thing on earth, and in 1589 only a few ships, among them the yearly Manila galleons, had ever crossed it.

Look closely

- Find the *Victoria*. How did Ortelius make her look important?
- Find South America on the right. Can you find the strait near its southern tip?
- Look along the bottom of the map. Ortelius drew a huge southern land there that no one had ever seen. Would Captain Cook, two hundred years later, find it?
- Find the decorated frames around the title. You will draw one like them in Lesson 9.3.

Talk about it

1. Why do you think Ortelius put the *Victoria* right in the middle of his map?
2. What parts of this map were probably right, and what parts were guesses?
3. If you made an explorer card for Ortelius, what would his "tool" be?

PROJECT: MY EXPLORER CARD DECK

You will make a deck of at least 16 trading cards for the explorers, navigators, mapmakers and missionaries of this course. Every number on every card must be true, and every card gets an honest truth box. Then you will play the Explorer Cards game with your family.

You will need

- 16 or more index cards (3 × 5 inches) or cardstock cut to the same size
- Colored pencils and a fine black pen
- Your map notebook and your lessons from Units 1–8
- An atlas or globe for checking latitudes
- A zip bag or small box to keep the deck

Steps

1. Choose your 16 cards. Here are good ones, with a starting fact for each: Prince Henry the Navigator (sponsored voyages down Africa, 1400s); Bartolomeu Dias (Cape of Good Hope, 1488); Christopher Columbus (1492); Vasco da Gama (India, 1498); Magellan and Elcano (around the world, 1519–1522); Gerardus Mercator (his map, 1569); John Harrison (H4, 1759); James Cook (71°10' S, 1774); William Carey (India, 1793); David Livingstone (Victoria Falls, 1855); Hudson Taylor (China Inland Mission, 1865); Mary Slessor (Calabar, 1876); Matthew Henson and Robert Peary (near the North Pole, 1909); Roald Amundsen (South Pole, 1911); Ernest Shackleton (*Endurance*, 1914–1917); Edmund Hillary and Tenzing Norgay (Everest, 1953).
2. On the front of each card, write the name and country, draw the person or the ship, and add a small sketch map showing where they went.
3. On the back, write the statistics: Year, Farthest latitude reached (if you know it from your lessons) and one more number such as days, miles or crew. Check every number in your lessons or an atlas. If you cannot check a number, leave it off.
4. Write the tool that made the journey possible.
5. Write a truth box of one or two sentences: one great deed, and one real wrong if there was one. Use plain words, as a fair judge would.
6. Give each card a Courage score and a Skill score from 1 to 10. On a separate sheet, write one sentence defending each score.
7. Store the deck in its bag and play the game at the end of this lesson.

Tips

- Use the same layout on every card so the statistics are easy to compare in the game.
- A missionary's "tool" might be a printing press, a translated Bible, a canoe or a medicine chest.
- If a record is disputed, like Peary and Henson's claim to the North Pole, write "claimed" and say so in the truth box.

Check your work

- Every year and latitude on my cards matches my lessons or an atlas.
- Every card has a tool and an honest truth box.
- I can defend my courage and skill scores with a reason.

MAP NOTEBOOK

1. Draw a world map and trace the route of the *Victoria*: Spain, the coast of South America, the Strait of Magellan, across the Pacific to the Philippines and the Spice Islands, around Africa and home.
2. Make a timeline from 1400 to 2000 and place each card from your deck on it.
3. Draw a latitude ladder from 0° to 90° S and mark Dias (about 35° S), Cook ($71^\circ 10'$ S), Shackleton's 1909 farthest south ($88^\circ 23'$ S) and Amundsen (90° S).

From history. When the *Victoria* stopped at the Cape Verde Islands on the way home in July 1522, the crew found something strange. Antonio Pigafetta, an Italian who kept a careful journal of the whole voyage, had written down every day, yet the people on shore said it was a day later than his record showed. By sailing west around the world, following the sun, the crew had lost a whole day. It was the first time anyone had met the puzzle that the International Date Line solves today. The king gave Elcano a coat of arms with a globe and the Latin words *Primus circumdedisti me*: "You were the first to sail around me."

WORKED EXAMPLES

Example 1. Captain Cook reached $71^\circ 10'$ S in 1774. Amundsen reached the South Pole, $90^\circ 00'$ S, in 1911. How many degrees and minutes farther south did Amundsen go? How many nautical miles is that?

(Use the map or drawing "Use the latitude statistic on two cards to compare explorers." shown earlier in this lesson.)

1. Subtract the latitudes. Write 90° as $89^\circ 60'$ so you can subtract the minutes: $89^\circ 60' - 71^\circ 10' = 18^\circ 50'$.
2. Change degrees to nautical miles: $18 \text{ degrees} \times 60 = 1,080$ nautical miles.
3. Each minute is 1 nautical mile, so add 50: $1,080 + 50 = 1,130$ nautical miles.
4. Check: $71^\circ 10' + 18^\circ 50' = 89^\circ 60' = 90^\circ$. Correct.

Answer: Amundsen went $18^\circ 50'$ farther south, about 1,130 nautical miles (about 1,300 miles, or 2,100 km).

PRACTICE

1. **EASY** Put these cards in order by year, earliest first: Amundsen, Dias, Livingstone at Victoria Falls, William Carey sails for India, Hillary and Tenzing.

2. **MEDIUM** On January 9, 1909, Ernest Shackleton's party turned back at $88^{\circ}23'$ S. How far were they from the South Pole in degrees and minutes, and in nautical miles?
3. **MEDIUM** About 270 men sailed with Magellan in 1519, and 18 came home on the *Victoria* in 1522. About what fraction came home?
4. **HARD** Amundsen left his base for the pole on October 20, 1911, and reached it on December 14, 1911. How many days did the journey to the pole take? (October has 31 days and November has 30.)
5. **CHALLENGE** Write the truth box for Vasco da Gama or Christopher Columbus in two sentences: one great deed and one real wrong.

COMMON MISTAKES

- Making up a number to fill a blank on a card. If you cannot check it, leave it off. A card game is only as good as its facts.
- Subtracting latitudes as if minutes were decimals. $90^{\circ} - 71^{\circ}10'$ is $18^{\circ}50'$, not 18.9° or $19^{\circ}90'$.
- Thinking a truth box must be all praise or all blame. Most explorers did great things, and some also did real wrongs. Say both plainly.

Make it a game • Explorer Cards Showdown. Deal the deck evenly. Each player holds the cards face down and turns over the top one. The first player picks a category and reads it: **Earliest Year** (the earlier year wins), **Farthest Latitude** (the number farther from the equator wins), **Courage** or **Skill** (higher wins). The winner takes both cards, but only after telling one true fact from the card's truth box. A tie goes to whoever can name the explorer's tool first. Play until one player has all the cards or for 15 minutes.

Scripture. "By faith Abraham, when he was called to go out into a place which he should after receive for an inheritance, obeyed; and he went out, not knowing whither he went." (Hebrews 11:8, KJV)

Abraham was the first great traveler of faith. Many missionaries in your deck, like Carey, Taylor and Slessor, set out the same way, not knowing exactly what lay ahead, but trusting the God who did.

Practice answers

1. Dias (1488), Carey (1793), Livingstone (1855), Amundsen (1911), Hillary and Tenzing (1953).
2. $89^{\circ}60' - 88^{\circ}23' = 1^{\circ}37'$. That is $60 + 37 = 97$ nautical miles. Shackleton turned back so his men would not die on the way home.
3. $18 \div 270 = 1/15$. About 1 man in every 15 came home on the *Victoria*.
4. October 20 to October 31: 11 days. November: 30 days. December 1 to 14: 14 days. $11 + 30 + 14 = 55$ days.
5. Sample, da Gama: He opened the sea route from Europe to India in 1498, a voyage of great skill and endurance. On his second voyage in 1502 he used terrible cruelty, attacking ships and bombarding Calicut. Sample, Columbus: He crossed the Atlantic in 1492 and opened the

Americas to Europe. As governor of Hispaniola he ruled harshly, and the native Taíno people were forced into labor and suffered greatly.

9.3 MAKE AN OLD-STYLE MAP

OBJECTIVES

- Name the parts of an old-style map: the compass rose, rhumb lines, the cartouche, the scale and the decorations in unknown places.
- Read a 16-point compass rose and give each point as a bearing in degrees, such as NE = 45° and SSW = $202\frac{1}{2}^\circ$.
- Draw and decorate an old-style map of a real or imagined place, with a true compass rose, a working scale and a cartouche.

Warm-up. Look at any map in your house: a road map, a park brochure or a map in a book. Hunt for five things in 5 minutes: the title, the north arrow or compass rose, the scale, the key, and the mapmaker's name or date. Where on the page did the mapmaker put each one? Was any of it decorated?

Watch. *How To Draw A Pirate Treasure Map* (Art for Kids Hub, 10:52).

<https://www.youtube.com/watch?v=auuS-cWPNT0>

Before the project: draw along to make a treasure-style map, then add a compass rose, a scale bar and a sea creature in the old style.

Note: Captions were not available to check; preview it first.

KEY TERMS

compass rose

A star-shaped drawing on a map that shows north, south, east, west and the directions in between.

rhumb lines

Straight lines drawn out from a compass rose across an old sea chart, so a pilot could lay a ruler along a steady compass course.

cartouche

A decorated frame on a map, often like a scroll or a carved shield, that holds the title, the mapmaker's name, the date or the scale.

scale bar

A marked line that shows how far a real distance is on the map, such as 1 inch = 10 miles.

bearing

A direction given in degrees clockwise from north: north is 0° , east 90° , south 180° and west 270° .

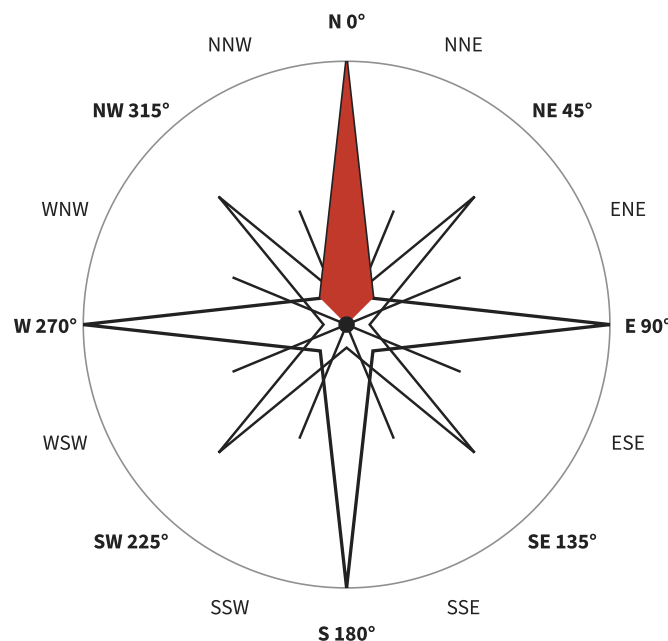
CORE IDEAS

The story. In 1539, in the city of Venice, a Swedish priest named Olaus Magnus printed the largest and most detailed map of the northern lands anyone had yet made. He had left

Sweden after its king broke with the Roman Catholic Church, but he never stopped loving the cold North. His *Carta Marina* (Sea Chart) was cut on nine wooden blocks and printed on nine sheets that fit together, about 4 feet tall and 5½ feet wide (125 by 170 cm). It shows Scandinavia, Iceland and the northern seas, with reindeer, skiers, fishermen and battles on the land. And in the sea, Olaus drew **monsters**: a giant sea serpent wrapped around a ship, sailors anchored to a whale they mistook for an island, and the great whirlpool off the coast of Norway. Only two copies of the 1539 printing are known today, one in Uppsala, Sweden, and one in Munich, Germany.

How it works. Old maps were works of art, but every decoration had a job. The **compass rose** showed directions; on the old sea charts called portolans, straight **rhumb lines** ran out from the roses so a pilot could lay a ruler along a course. Mariners divided the circle into 32 points, each $11\frac{1}{4}^\circ$ apart, and learned to “box the compass” by saying them all in order. North was often marked with a fleur-de-lis, and many charts marked east with a small cross, toward Jerusalem and the Holy Land. The **cartouche** was a fancy frame holding the title, the maker’s name, the date and often the **scale**. The sea monsters were partly sailors’ tales, partly real creatures seen badly (whales, walruses, giant squid), and partly a mapmaker’s honest way of saying, “These waters are wild and little known.”

The big idea. A beautiful map must still be a true map. As explorers sailed farther, mapmakers like Mercator and Blaeu filled the blank spaces with coastlines and soundings, and the monsters slowly swam off the charts. The Bible already told the sailors that the sea is full of living things God made, “both small and great beasts” (Psalm 104:25), and real wonders like the blue whale and the giant squid are stranger than many of the old monsters. Today you will make a map the old way, with a true compass rose, a scale that works and a cartouche, and you may put a sea monster only where your map is honestly unknown.



A 16-point compass rose. The points are $22\frac{1}{2}^\circ$ apart; a sailor’s full rose has 32 points, $11\frac{1}{4}^\circ$ apart.

PICTURE STUDY



Carta Marina (Sea Chart of the Northern Lands), Olaus Magnus, 1539 · Woodcut printed on nine sheets · Uppsala University Library, Sweden (one of two known copies of the 1539 printing; the other is in the Bavarian State Library, Munich)

Olaus Magnus spent about twelve years gathering what he knew of the North, from his own travels and from sailors, traders and fishermen, and then put it all on this map. It is less like a modern map and more like a giant picture book: every space is full of stories. He later wrote a long book, the *History of the Northern Peoples* (1555), to explain them.

Look first at the land, then at the sea. On the land Olaus drew what he had seen or heard from many people. In the sea, especially far from the coasts, his drawings come more from sailors' tales.

Look closely

- Find the sea serpent wrapped around a ship off the coast of Norway.
- Find a whale with sailors on its back. What did they think it was?
- Find people on skis or on sleds. What does this tell you about winter in the North?
- Look for a compass rose or straight lines across the sea. How would they help a sailor?

Talk about it

1. Which drawings do you think show real things, and which show tales? How can you tell?
2. Why might a mapmaker draw monsters in waters few sailors had crossed?
3. What would you put on a map of your own town to show the people who live there?

Safety first. Use hot tea or coffee for staining only with an adult's help, and let the paper cool before you touch it. Do not burn the edges of your map; tear them gently instead.

PROJECT: MY OLD-STYLE MAP

You will draw a map in the style of the 1500s and 1600s, of your neighborhood, your backyard or an imagined island. It must have a true compass rose, a cartouche with a title, your name, the date and a working scale, a few rhumb lines, and at least one sea creature in the unknown waters.

You will need

- A large sheet of heavy white or cream paper (about 11 × 17 inches)
- A cup of cold strong tea and a sponge or paper towel (optional, for an old look)
- A pencil, eraser, ruler and a protractor
- A fine black pen and colored pencils or watercolors
- A round lid or compass for drawing circles
- Pictures of the Carta Marina and the Ortelius Pacific map from Lesson 9.2 for ideas

Steps

1. Optional: with an adult, sponge cold tea over the paper and let it dry flat overnight. Tear the edges a little for an old look.
2. Choose your place. Sketch its coastline or outline lightly in pencil, leaving open “sea” or “unknown land” around it.
3. Choose a scale and measure carefully. For example, if your island is 10 miles long and you draw it 5 inches long, your scale is 1 inch = 2 miles.
4. Draw a compass rose in an open corner. Use a protractor to mark 16 points $22\frac{1}{2}^\circ$ apart, starting with north straight up. Label N, NE, E, SE, S, SW, W and NW, and decorate north with a fleur-de-lis.
5. With a ruler, draw a few faint rhumb lines from the rose across the sea along the 16 directions.
6. In another corner draw a cartouche: a scroll, shield or frame with leaves. Inside, write the title in fancy letters, “Drawn by” your name, the year, and your scale bar.
7. Add little pictures: ships, towns, mountains drawn as small hills, forests as tiny trees. Put a sea monster or a whale only in the waters you do not know well.
8. Go over the lines in ink and add color. Then check: does every direction on your map match the compass rose?

Tips

- Draw the most important parts (coastline, compass rose, cartouche) first and the decorations last.
- Old mapmakers wrote place names along coasts at right angles to the shore, so you could read them as you sailed past.

- A real animal drawn carefully, like a whale, walrus or giant squid, can be just as wonderful as a made-up monster.

Check your work

- My compass rose has 16 points, correctly labeled, with north at the top.
- My cartouche holds a title, my name, the date and a working scale bar.
- I can measure one distance on my map with my scale and tell how far it is.

MAP NOTEBOOK

1. Practice three cartouche shapes: a scroll, a shield and a frame with leaves. Choose your favorite for your map.
2. Draw a 16-point compass rose and write the bearing in degrees beside each of the eight main points.
3. Draw one sea monster from the Carta Marina, and next to it draw the real animal that might have started the tale.

From history. The famous words “Here be dragons” appear in Latin, *HC SVNT DRACONES*, on the Hunt-Lenox Globe, a small copper globe made about 1510 and now kept at the New York Public Library. The words sit near the coast of eastern Asia. Almost no other old map uses the phrase, but people loved it so much that it became the saying everyone remembers about old maps.

WORKED EXAMPLES

Example 1. On your old-style map, a ship sails out of the harbor toward SSW. What is that bearing in degrees? If the ship turns around and sails straight back, what point and bearing does it steer?

(Use the map or drawing “Opposite points are always 180° apart.” shown earlier in this lesson.)

1. Find SSW on the compass rose. Its name means “south-southwest”: it sits halfway between S and SW.
2. S is 180° and SW is 225°. Halfway between: $(180 + 225) \div 2 = 202\frac{1}{2}^\circ$.
3. To go straight back, turn halfway around the circle: add or subtract 180°. $202\frac{1}{2}^\circ - 180^\circ = 22\frac{1}{2}^\circ$.
4. $22\frac{1}{2}^\circ$ is halfway between N (0°) and NE (45°), which is the point NNE.

Answer: SSW is a bearing of $202\frac{1}{2}^\circ$. To sail straight back, steer NNE, a bearing of $22\frac{1}{2}^\circ$.

PRACTICE

1. **EASY** Give the bearing in degrees for E, S and NW.
2. **MEDIUM** What is the bearing of ESE? What point is exactly opposite it?

(Use the map or drawing “Use the rose to find ESE and its opposite.” shown earlier in this lesson.)

3. **MEDIUM** A sailor’s full compass rose has 32 points spaced evenly around the circle. How many degrees apart are they?
4. **HARD** The cartouche on your map says 1 inch = 2 miles. Your island measures $6\frac{1}{2}$ inches from its northern cape to its southern cape. How long is the island in miles? About how many kilometers is that? (1 mile is about 1.6 km.)
5. **CHALLENGE** In two or three sentences, explain why old mapmakers drew sea monsters, and why they disappeared from later charts.

COMMON MISTAKES

- Labeling the in-between points backwards, such as writing WSW between N and W. The letter said first is the main direction it is closest to: NNW is next to N, WNW is next to W.
- Drawing a beautiful cartouche with no scale. A map without a scale cannot tell you how far anything is.
- Thinking old maps said “Here be dragons” everywhere. That Latin phrase is known on only one or two very old objects; most old maps simply drew pictures or left the space blank.

Make it a game • Box the Compass. Sailors once had to “box the compass” by saying all the points in order. Stand in the middle of the room facing north. A caller names a point, such as “ESE!” Turn to face it and call out its bearing in degrees. A right answer scores a point. For a harder round, the caller says a bearing, such as “ 225° ,” and you must turn and name the point (SW). Then try saying all 16 points in order, clockwise from north, as fast as you can without a mistake.

Scripture. “So is this great and wide sea, wherein are things creeping innumerable, both small and great beasts. There go the ships: there is that leviathan, whom thou hast made to play therein.” (Psalm 104:25-26, KJV)

The old mapmakers were right that the sea is full of great creatures. The psalmist saw them not as terrors but as things God made and set in the sea “to play therein.” Draw your sea creatures with wonder.

Practice answers

1. E = 90° , S = 180° , NW = 315° .
2. ESE is halfway between E (90°) and SE (135°): $112\frac{1}{2}^\circ$. The opposite point is WNW, at $112\frac{1}{2}^\circ + 180^\circ = 292\frac{1}{2}^\circ$.
3. $360 \div 32 = 11\frac{1}{4}$ degrees (11.25°).
4. $6\frac{1}{2} \times 2 = 13$ miles. $13 \times 1.6 \approx 21$ km.
5. Monsters came from sailors’ tales and from real animals seen badly, and they filled waters that were little known, warning that the sea there was wild. As more ships sailed those waters

and mapmakers learned the true coasts, depths and dangers, they replaced the guesses with real information, and the monsters went away.

9.4 ORIENTEERING IN THE PARK

OBJECTIVES

- Hold a compass and follow a bearing in degrees, and find the back bearing by adding or subtracting 180°.
- Measure your own pace and use it with a map scale to walk a set distance, which is dead reckoning on foot.
- Read an orienteering map with a start triangle, numbered control circles and a finish, and run a short course in a park.

Warm-up. Measure out 100 feet (30 m) in a hallway, driveway or yard with a tape measure. Walk it at your normal speed and count every time your *left* foot lands. That number is your pace count for 100 feet. Walk it twice more and take the middle number. Write it in your notebook: you will need it today.

Watch. *Orienteering Amazing adventures for the young and free* (Orienteering Australia, 1:35). https://www.youtube.com/watch?v=a_rq-nP10UM

Before the project: watch this short clip to see young people racing through the woods with map and compass, then get ready for your own park course.

Note: Captions were not available to check; preview it first. It is a 95-second promo from Orienteering Australia that shows the sport but does not teach how to use a compass or take a bearing.

Backup video. *Start Orienteering // A Newcomer's Guide // Presented by Graham Gristwood* (South London Orienteers / On The Red Line, 5:30).

<https://www.youtube.com/watch?v=26Zc5AVkFis>

Before the project: watch this newcomer's guide to orienteering, how to read the map and find the control flags. Note: Captions were not available to check; preview it first.

KEY TERMS

orienteering

A sport and skill of finding your way from point to point across land with a map and a compass.

control

A checkpoint on an orienteering course, shown on the map as a numbered circle and marked in the field with an orange-and-white flag.

baseplate compass

A compass mounted on a clear, flat plate with a ruler and a direction-of-travel arrow, made for use on a map.

pace

In orienteering, two steps: counted each time the same foot lands. Many children cover about 4 or 5 feet in one pace.

back bearing

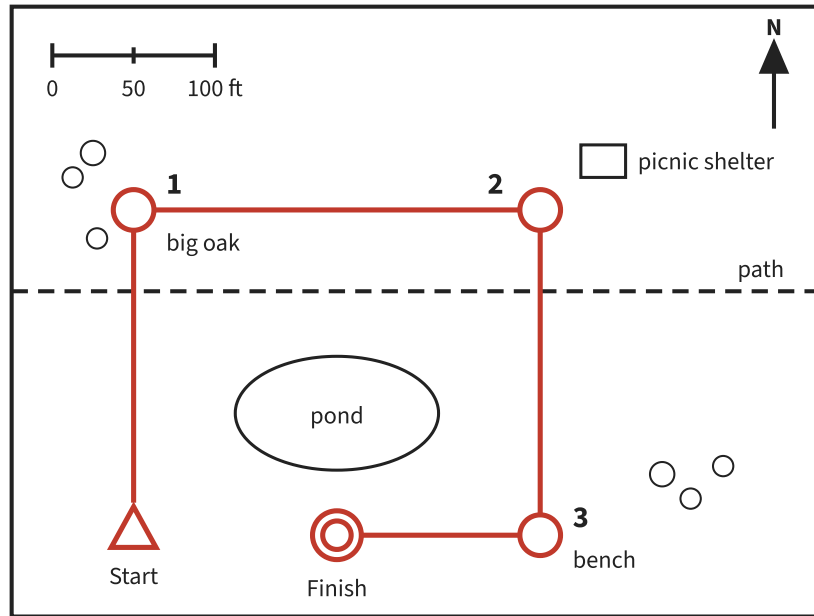
The direction straight back the way you came: your bearing plus or minus 180°.

CORE IDEAS

The story. In the late 1800s, army officers in Norway and Sweden trained soldiers to cross forests with only a map and a compass. In 1897 a club in Norway held one of the first public races of this kind, and in 1919, near Stockholm, a Swedish officer and youth sports leader named Major Ernst Killander set a course through the woods for a large public race. He wanted young people to love the outdoors and learn to think while they ran. He is often called the father of **orienteering**. In the early 1930s three Swedish brothers named Kjellström and their friend Gunnar Tillander designed the clear **baseplate compass** that lies flat on a map, and the sport spread around the world. Today children and grandparents run orienteering courses in parks and forests all over America.

How it works. An orienteering course is drawn on the map with a **triangle** for the start, numbered **circles** for the controls, and a **double circle** for the finish. For each leg you do what Vasco da Gama's pilots and Captain Cook's officers did at sea: you find a **direction** and a **distance**. Set the compass to the bearing, hold it flat in front of your belly, turn your whole body until the red needle sits in the outline arrow, and walk where the travel arrow points. For distance, use the map's scale bar and your **pace count**. If your pace is 5 feet and the leg is 250 feet, count 50 paces. That is **dead reckoning** on foot, the same method you learned in Unit 2.

On the map. Good orienteers do not only count. They look for **handrails**, long features like a path, fence or stream that lead toward the control, and for an **attack point**, an easy-to-find landmark near it, such as the corner of a pond. Dead reckoning drifts a little with every step, just as Boxfall's reckoning on the *Titanic* did, so checking against the land is how you stay found. Today your phone can tell you where you are from GPS satellites, but batteries die and signals fail in deep woods and canyons. A person who can read a map, hold a compass and count paces can still find the way home. That is the last skill of the Map Lab, and it is one you can use for the rest of your life.



A practice course. Start (triangle) to control 1 is due north, 1 to 2 due east, 2 to 3 due south, and 3 to the finish (double circle) due west.

PICTURE STUDY



Wanderer above the Sea of Fog, Caspar David Friedrich, about 1817 · Oil on canvas · Hamburger Kunsthalle, Hamburg, Germany

Caspar David Friedrich was a German painter who loved mountains, forests and seashores and painted them with deep wonder. Here a traveler has climbed to a high rock and stands looking out over a valley filled with fog. Only the tops of ridges and far mountains poke through.

Friedrich does not show us the man's face. Instead we stand behind him and look where he looks. Every orienteer and every explorer knows this moment: you reach a high place and try to match the land in front of you to the map in your hand.

Look closely

- Find the walking stick. What does it tell you about how the man got here?
- Find the ridges and peaks that rise out of the fog. Which looks closest? Which looks farthest away?
- Look at the colors near the bottom and near the top. How does Friedrich make the far mountains seem far?
- Where is the light coming from?

Talk about it

1. If this traveler had a map and compass, which landmarks could he use to find where he is?
2. Why might fog make finding your way hard, even for someone with a good map?
3. How does this painting make you feel about the world God made?

Safety first. Always orienteer with an adult or in a group, and agree on the park boundary and a meeting place before you start. Carry water and a whistle, walk (do not run) near water and roads, and keep your compass away from magnets, phones and metal benches when you take a bearing.

PROJECT: SET AND RUN A PARK ORIENTEERING COURSE

First you will learn your compass and your pace in the yard. Then, with an adult, you will set a four-leg course in a park or large yard, draw its map, and run it. Finally, you will trade courses with a family member and run theirs.

You will need

- A baseplate compass (sold cheaply at outdoor and sporting goods stores)
- A 100-foot tape measure, or a 50-foot one used twice
- Five markers for controls: orange-and-white paper flags, or paper plates with a number and a secret letter on the back
- Clipboard, graph paper, a pencil and a ruler
- A watch or stopwatch, water bottle and whistle
- Your pace count from the warm-up

Steps

1. Learn the compass. Turn the dial until the bearing you want (try 90°) lines up with the travel arrow. Hold the compass flat at your belly and turn your body until the red end of

the needle sits inside the outline arrow ("red in the shed"). Now walk where the travel arrow points.

2. Practice a square in the yard: walk 10 paces at 0°, 10 at 90°, 10 at 180° and 10 at 270°. If you end where you started, your compass work is good.
3. In the park, with an adult, choose a start and four controls at things easy to see on a map: a big tree, a shelter, a bench, a corner of a pond, a gate.
4. For each leg, take a bearing with the compass and count paces. Write them down: "Start to 1: 0°, 40 paces." Change paces to feet with your pace count.
5. Draw the map on graph paper with north at the top. Choose a scale, such as 1 square = 25 feet, and draw paths, water, buildings and big trees. Mark the start with a triangle, controls with numbered circles and the finish with a double circle. Add a scale bar and a north arrow.
6. Hang your markers. Write each one's secret letter on your answer sheet.
7. Give your map to a family member. Time them as they run the course in order and write down the secret letters. Then run their course while they time you.
8. Afterward, write in your notebook which leg was hardest and which landmarks helped most.

Tips

- Pick a far landmark straight along your bearing, like a tree or post, and walk to it. Then take the bearing again. You will drift less than if you stare at the compass.
- Uphill, in tall grass or in sand your paces get shorter, so you will need more of them.
- Before each leg, say the plan out loud: "Bearing 90, fifty paces, picnic shelter on my right after the path."

Check your work

- I can set a bearing on my compass and follow it.
- I know my pace count and can turn feet into paces.
- I drew a map with a start triangle, numbered controls, a finish, a scale bar and north arrow, and someone else could follow it.

MAP NOTEBOOK

1. Draw your baseplate compass and label the needle, the dial (housing), the outline arrow, the direction-of-travel arrow and the ruler.
2. Copy the practice course map and write the bearing and the distance in feet beside each leg.
3. Draw the five most common orienteering map symbols you used today (start, control, finish, water, path) and make a key.

From history. Orienteering came to the United States after World War II. Björn Kjellström, one of the Swedish brothers who designed the baseplate compass, came to America and worked to spread the sport, and his book *Be Expert with Map and Compass*

taught a generation of Scouts and hikers to find their way. Today orienteering clubs across the country set permanent courses in parks, where anyone can print a map and go.

WORKED EXAMPLES

Example 1. Sam walks 100 feet and counts 20 paces. On the practice map, the leg from Control 1 to Control 2 is 250 feet long and runs due east. What bearing should Sam set, and how many paces should Sam count?

(Use the map or drawing “The leg from Control 1 (big oak) to Control 2 (picnic shelter) runs due east.” shown earlier in this lesson.)

1. Find Sam’s pace length: $100 \text{ feet} \div 20 \text{ paces} = 5 \text{ feet per pace}$.
2. Divide the leg by the pace length: $250 \text{ feet} \div 5 \text{ feet} = 50 \text{ paces}$.
3. Due east is a bearing of 90° .
4. Check: $50 \text{ paces} \times 5 \text{ feet} = 250 \text{ feet}$. Correct.

Answer: Set a bearing of 90° and count 50 paces.

PRACTICE

1. **EASY** On the practice map, what bearing do you follow from the Start to Control 1? From Control 2 to Control 3?
(Use the map or drawing “North is at the top.” shown earlier in this lesson.)
2. **MEDIUM** The scale bar on the practice map stands for 100 feet. The leg from Start to Control 1 is 2 scale bars long, Control 1 to 2 is $2\frac{1}{2}$ bars, Control 2 to 3 is 2 bars, and Control 3 to the Finish is $1\frac{1}{4}$ bars. How long is each leg in feet, and how long is the whole course?
(Use the map or drawing “Compare each leg with the scale bar.” shown earlier in this lesson.)
3. **MEDIUM** You reach Control 2 and realize you missed Control 1’s secret letter. What bearing takes you straight back from Control 2 to Control 1?
4. **HARD** Your pace is 5 feet. How many paces is the whole 775-foot practice course? If you walk about 1 pace every $1\frac{1}{2}$ seconds, about how many minutes will the walking take?
5. **CHALLENGE** Jo’s pace on the sidewalk is 5 feet, but on bumpy grass it is only 4 feet. Jo counts 50 paces on the grass for the 250-foot leg to the picnic shelter. Where does Jo stop? In two sentences, explain how a good orienteer would still find the control.

COMMON MISTAKES

- Turning the compass dial while you walk. Set the bearing once, then turn your whole body, not the dial, to put red in the shed.
- Taking a bearing next to a car, a metal bench or a phone. Metal and magnets pull the needle off north.
- Counting every step instead of every pace. A pace is two steps, counted each time the same foot lands.

Make it a game • Compass Treasure Hunt. One player hides a small treasure in the yard and writes a three-leg clue card from a starting post, such as “45°, 12 paces; 180°, 8 paces; 270°, 10 paces.” The hunter follows the clues with a compass and their own pace count. Finding the treasure within 3 steps wins a point for both players: the hunter for good walking and the hider for good clues. Switch roles. For a harder game, give only the first leg and a riddle about a landmark for the second.

Scripture. “Trust in the LORD with all thine heart; and lean not unto thine own understanding. In all thy ways acknowledge him, and he shall direct thy paths.” (Proverbs 3:5-6, KJV)

A compass does not pull you along; you must trust it and turn to follow it, even when your feelings say another way. God’s Word is a surer guide than any compass, and He promises to direct the paths of those who trust Him.

Practice answers

1. Start to Control 1 is due north, 0°. Control 2 to Control 3 is due south, 180°.
2. Start to 1: 200 ft. 1 to 2: 250 ft. 2 to 3: 200 ft. 3 to Finish: 125 ft. Total: $200 + 250 + 200 + 125 = 775$ feet (about 236 m).
3. You came on a bearing of 90°. The back bearing is $90^\circ + 180^\circ = 270^\circ$, due west.
4. $775 \div 5 = 155$ paces. $155 \times 1\frac{1}{2} = 232\frac{1}{2}$ seconds, a little under 4 minutes ($232\frac{1}{2} \div 60 \approx 3.9$).
5. $50 \times 4 = 200$ feet, so Jo stops 50 feet short of the shelter. A good orienteer looks up for landmarks and handrails, like the path and the shelter itself, and checks the land against the map instead of trusting the count alone, the way a navigator checks dead reckoning against a landmark or a star sight.

UNIT 9 REVIEW

Answer each question. Show your work for calculations and use complete sentences for explanations. The review is worth 50 points.

1. (8 pts) A ship radios its position as $43^{\circ}20'$ N, $55^{\circ}40'$ W. Describe where to plot it between the whole-degree lines. On a map of the North Atlantic, is 56° W to the left or the right of 55° W?
2. (9 pts) The Titanic's distress call gave $41^{\circ}46'$ N, $50^{\circ}14'$ W. Who worked out that position, and by what method? The wreck was found at about $41^{\circ}43'$ N. How many nautical miles apart are the two latitudes?
3. (8 pts) Who led the first voyage around the world, and who finished it? What year did the *Victoria* return, and about how many of the roughly 270 men came home on her?
4. (8 pts) Captain Cook reached $71^{\circ}10'$ S in 1774; Amundsen reached 90° S in 1911. How much farther south did Amundsen go, in degrees and minutes and in nautical miles? Then write a two-part truth box for one explorer of your choice: one great deed and one real wrong (or say plainly that you know of none).
5. (9 pts) Name three parts of an old-style map and the job of each. Then give the bearing in degrees of NE, SSW and W.
6. (8 pts) Your pace is 5 feet. An orienteering leg runs 300 feet on a bearing of 135° . How many paces do you count, and what is the back bearing? On an orienteering map, what do a triangle, a numbered circle and a double circle mean?

UNIT PROJECT: MY MAP LAB NAVIGATOR'S CHEST

Gather your Map Lab work into a "navigator's chest" (a decorated box or folder). It must hold: your finished old-style map with a 16-point compass rose, rhumb lines, a cartouche with title, name, date and a working scale, and at least one sea creature in unknown waters; your deck of at least 16 explorer cards with checked statistics and honest truth boxes; your Find the Ship chart with three plotted rescues; and the map and bearing-and-pace log of the orienteering course you set in a park.

Add a short letter, as if to a young sailor about to go to sea, explaining in one paragraph how latitude and longitude, a compass bearing and a pace or speed let a person know where they are without GPS.

- **Accuracy:** Positions are plotted correctly, compass points and bearings are labeled correctly, and every number on the explorer cards is true and checkable.
- **Honesty:** Truth boxes give real deeds and, where they belong, real wrongs in plain words, and disputed claims are marked as disputed.
- **Navigation:** The orienteering map has a start, numbered controls, a finish, a scale bar and a north arrow, and the log gives a correct bearing and pace count for each leg.
- **Care and explanation:** The maps and cards are neat and beautiful, and the letter clearly explains how navigators find their position.

Answer key

1. Latitude: one-third of the way from 43° N up to 44° N (20 of 60 minutes). Longitude: two-thirds of the way from 55° W toward 56° W (40 of 60 minutes), just east of the 56° line. 56° W is to the left (west) of 55° W.
2. Fourth Officer Joseph Boxhall worked it out by dead reckoning (speed, heading and time since the last fix). $46' - 43' = 3'$, which is 3 nautical miles.
3. Ferdinand Magellan led it from 1519 until he was killed on Mactan in 1521; Juan Sebastián Elcano finished it, bringing the *Victoria* home to Spain on September 6, 1522, with 18 men.
4. $89^{\circ}60' - 71^{\circ}10' = 18^{\circ}50' = 18 \times 60 + 50 = 1,130$ nautical miles. Truth box: any accurate pair, e.g. Columbus crossed the Atlantic in 1492, but ruled Hispaniola harshly; or Henry the Navigator sponsored the voyages down Africa, but his captains began the Portuguese slave trade on the African coast.
5. Any three: compass rose (shows directions); rhumb lines (straight compass courses across the sea); cartouche (decorated frame holding the title, maker, date and often the scale); scale bar (shows real distance); sea monsters or pictures (decoration, and a sign of unknown waters).
 $NE = 45^{\circ}$, $SSW = 202\frac{1}{2}^{\circ}$, $W = 270^{\circ}$.
6. $300 \div 5 = 60$ paces. Back bearing: $135^{\circ} + 180^{\circ} = 315^{\circ}$ (NW). Triangle: start. Numbered circle: a control. Double circle: finish.