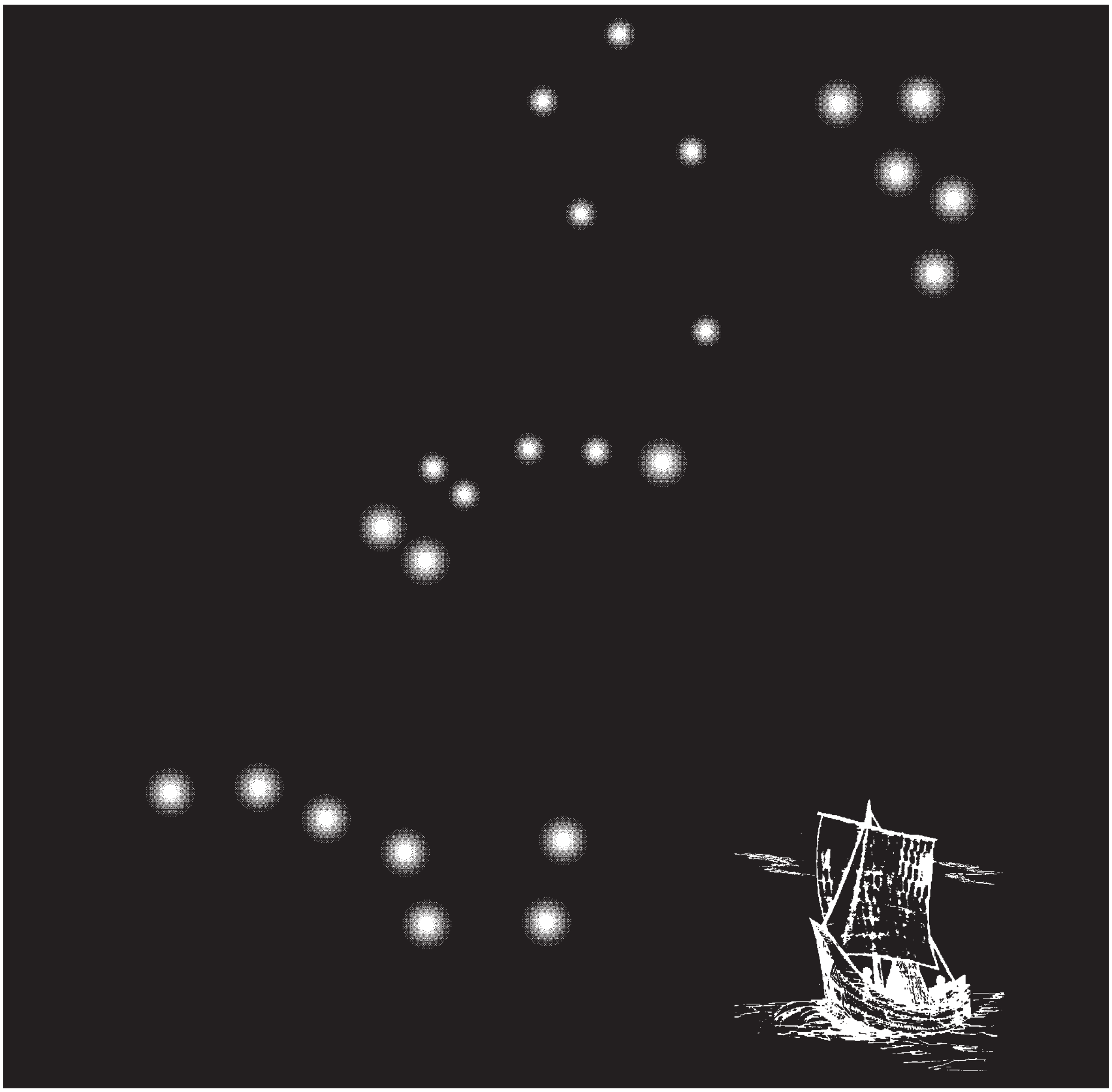
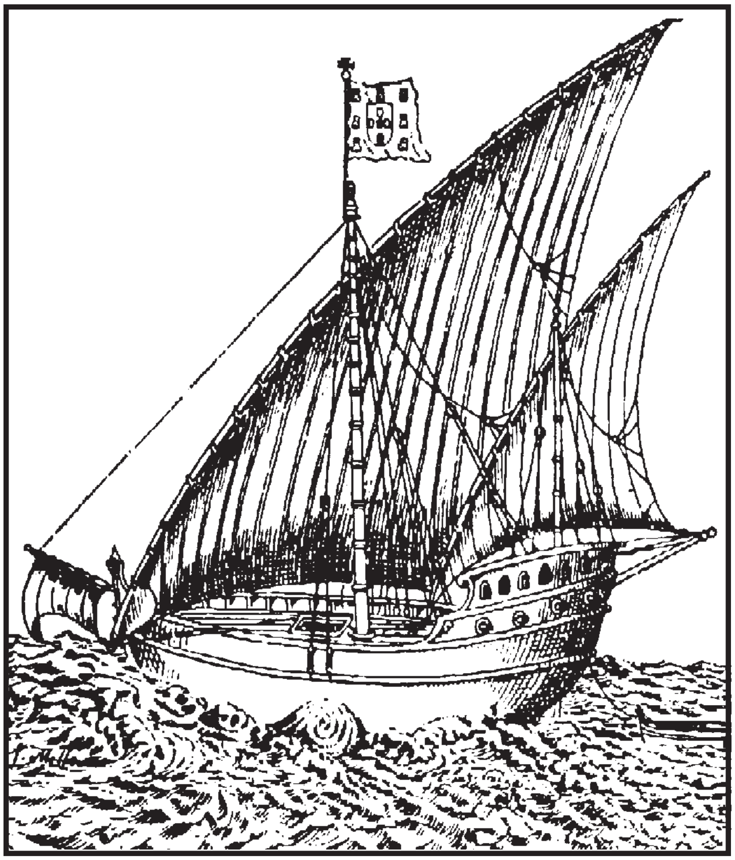
WHO "DISCOVERED" AMERICA?

A PROGRAM FROM THE HOLT PLANETARIUM



by Kevin Cuff, Edna DeVore, John Erickson, Alan Gould, John Hewitt, Steve Luntz, Cary Sneider, and Gregory Steerman

Jointly published by
the Lawrence Hall of Science, University of California, Berkeley, California
and the New York Hall of Science, Corona, New York



Development and publication of *Who "Discovered" America?* was made possible by a grant from the National Endowment for the Humanities (Grant Number GM 24046) and the National Science Foundation (Grant Number MDR-9053778), as part of an exhibition entitled *1492: Two Worlds of Science*. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Endowment for the Humanities and the National Science Foundation.

For latest information, valuable links, and resources relating to the PASS series, visit: https://gss.lawrencehallofscience.org/planetariums

LHS

Acknowledgments

Who "Discovered" America? was developed with support from the National Endowment for the Humanities (Grant Number GM 24046) and the National Science Foundation (Grant Number MDR-9053778), as part of an exhibition entitled *1492: Two Worlds of Science*, directed by Cary Sneider and Jennifer Meux White. Generous assistance was also provided by Nancy Beers and Ceres Bainbridge of Explorer's Hall, the National Geographic Society, who made available the Society's magnificent collection of images, books, and articles for this project.

Initial ideas for the program were developed by Cary Sneider as part of the overall design for the exhibition. The dedicated staff members who conducted the basic research for the program, designed the activities and special effects, wrote the script, as well as tested and refined the program with audiences at the Lawrence Hall of Science were: Edna DeVore (Project Coordinator), Kevin Cuff, John Erickson, Alan Gould, John Hewitt, Steve Luntz, Cary Sneider, and Greg Steerman.

Key consultants who contributed ideas and expert advice on this program included: Giuseppe Gambardella, Professor, Department of Communications, Computers, and Systems Science, University of Genoa, Genoa, Italy; Gene Brucker, Professor, History Department, University of California at Berkeley; John Heilbron, Professor, History Department, and Vice Chancellor, University of California at Berkeley; Lee Sprague, Native American performer with the Turtle Island Ensemble, San Francisco; and Dennis Jennings, Native American Health Center, San Francisco, California. Important substantive contributions were also made by Pierangelo Campodonico, Director of the Naval Museum of Pegli, Genoa, Itay; and Danilo Cabona, Director of Historical Archives, Port Authority of Genoa, Genoa, Italy.

Our special thanks to the following helpful individuals who provided open access to the libraries, museums, and scholars of Columbus's home town, Genoa, Italy, and the Region of Liguria: Enrico Beltrametti, Rettore of the University of Genoa, Genoa, Italy; Laura Malfatto, La Berio Library, Genoa, Italy; Ernesto Bruno Valenziano, Vice President of the Region of Liguria, Genoa, Italy; Luisa Massimo, President of the National Cancer Research Institute and Director of the Quincentennary Committee for the Region of Liguria; Piera Rum, Director of Bureau of Culture for the Region of Liguria, Genoa, Italy; and Enrico Bitossi of the State Archive, Genoa, Italy. These visits were kindly arranged by Professor Giuseppe Gambardella.

PASS Volume 10 Photos & Illustrations

Cover and title page, Polar Stars, Alan Gould; pp 3–5, 7, Compass & Eclipse Filter, Edna DeVore; p. 6, Quadrant, Gould; pp. 13–30, Slide Images, see sources on pp. 8–9; pp. 36–37, Shadow Sticks, Devore; pp. 40–44, Eratosthenes illustrations and Views of Earth, Carol Bevilacqua; p. 46–47, Classroom Star Projector, Devore; p. 50, Cartoon, Gould; pp. 52–53, Moon Modeling, Bevilacqua; p. 54, diagrams, Gould.

Planetarium Activities for Student Success (PASS)

Series Editors: Cary Sneider, Alan Friedman, and Alan Gould

If you have access to a planetarium for teaching about astronomy, space science, and other subjects, this series of books is for you. Designed for both experienced planetarium professionals and teachers who will be using a planetarium for the first time, these volumes provide a wealth of field-tested strategies and practical suggestions for presenting entertaining and educationally effective programs for students.

The first four books provide a general orientation to astronomy and space science education with applications for both the planetarium and classroom settings. Each of the remaining volumes presents a complete planetarium program and related classroom activities. We hope you will find the materials useful in your work with students and teachers, as well as springboards for your imagination and creativity.

Volume 1: Planetarium Educator's Workshop Guide

Participatory planetarium programs involve students actively in the planetarium environment. The most effective programs are both entertaining **and** educational. This guide introduces the theory and practice of developing effective planetarium programs through a series of thought-provoking activities and discussions.

Volume 2: Planetarium Activities for Schools

This volume provides a wealth of effective planetarium activities for elementary and middle school students, as well as ideas for developing new activities for students of any age.

Volume 3: Resources for Teaching Astronomy & Space Science

There is a wide spectrum of resources for teaching astronomy and space science in elementary and middle schools. This annotated resource guide has the best resources that we have found, including school curricula, books, periodicals, films, videos, slides, professional organizations, planetariums, and telescopes.

Volume 4: A Manual for Using Portable Planetariums

Primarily a "how-to" manual for setting up and using a portable planetarium, this guide has many suggestions useful for teaching school programs in **any** planetarium.

Volume 5: Constellations Tonight

In this participatory version of a classic night sky planetarium program, students receive star maps and have an opportunity to use them to find constellations in the planetarium sky. Classroom activities include creating constel-lations and using star maps.

Volume 6: Red Planet Mars

Students discover Mars three different ways during this planetarium program. They find the red planet by observing it over a period of several nights as it moves against the background stars. Then they view it through a telescope and try to map its surface. Finally they see Mars via space probes. Classroom activities involve students in modeling the solar system, and creating creatures that could survive under different planetary conditions.

Volume 7: Moons of the Solar System

This program begins with observations of the Earth's Moon and a modeling activity that shows why the Moon goes through phases and eclipses. Then the students look at Jupiter's four major moons on a series of nights and figure out how long it takes each one to circle Jupiter. Finally, the students journey through the Solar System to see many moons through the "eyes" of modern spacecraft. Classroom activities involve students in performing experiments in crater formation, using moon maps, and designing lunar settlements.

Volume 8: Colors and Space

What can we learn about the stars and planets from their colors? Answering this question requires a fundamental understanding of why we see color. During this program, students deepen their understanding through a series of activities in which they "travel" to an imaginary planet circling a red sun, and experiment with color filters and diffraction gratings. Related classroom activities include making secret messages that can only be decoded with color filters, and then using the same filters to view nebulae and planets.

Volume 9: How Big Is the Universe?

Based partly on ideas from the short film *Powers of Ten*, this program surveys distances and sizes of things in the universe. Starting with ordinary things on Earth that students are familiar with, they move to progressively more distant astronomical objects: the Moon, the Sun, the Solar System, nearby stars, the Milky Way galaxy, and clusters of galaxies. Students use various methods to determine distance: parallax, "radar," and comparing brightness of objects. Classroom activities include students writing their complete galactic address, making a parallax distance finder, finding the distance to the "Moon," and activities about the expanding universe.

Volume 10: Who "Discovered" America?

Students ponder the meaning of the word *discover* in this program. Can one "discover" a land where people are already living? Students learn the reasons and methods by which Columbus navigated to the "New World," and some of the impacts of his voyages on Native Americans. They also find that certain myths about Columbus are untrue. He was not, for example, alone in believing that the Earth is round. Students also learn about other explorers who "discovered" America long before Columbus's time. Classroom activities include determining the shape and size of the Earth, using quadrants to determine latitude, and modeling lunar eclipses.

Volume 11: Astronomy of the Americas

There are hundreds of Native American cultures, each with distinctive views of the heavens. There are also common threads in many of those cultures. In this program students visit five cultures: the Hupa people of Northern California, plains and mountain tribes that have used Medicine Wheel in Northern Wyoming, the Anasazi of Chaco Canyon in New Mexico, the Mayan people in Mexico and Central America, and the Incan people in Peru. Students observe moon cycles and changes in the sunrise and sunset positions on the horizon and learn how solar observations help Native Americans stay in tune with the harmonies of nature. Classroom activities include the Mayan and Aztec number systems, observing changes in real sunset positions, and learning how Venus can appear as either the "Morning Star" or "Evening Star."

Volume 12: Stonehenge

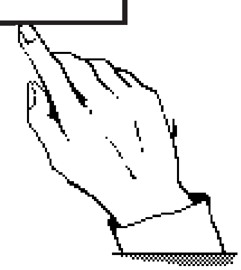
In this program, students learn what Stonehenge is and how it could have been used by its builders as a gigantic astronomical calendar. They also learn how astronomer Gerald Hawkins discovered Stonehenge's probable function, by actively formulating and testing their own hypotheses in the planetarium. Along the way, they learn a lot about apparent stellar, solar, and lunar motion, and the creation of the research field of "archeoastronomy." Classroom activities include constructing a special sundial to represent the entire yearly cycle of solar motion.

Who “Discovered” America?

CONTENTS

Planetarium Program

Classroom Activities



Who "Discovered" America?

Planetarium Show

Preface

When asked "Who 'discovered' America?" many students answer, "Columbus, of course!" Others say no—that the "Indians" were here first. Who is right? Are there other groups of people that might also claim to be "discoverers" of the Americas? A complete answer to the question, "Who 'Discovered' America?" depends partly on our understanding of history and archaeology, and partly on the meaning of the word *discover*. Does it mean the first time a person finds or explores something? Must a discoverer recognize the significance of the discovery? What if other people have discovered it before? Can there be more than one "discoverer" of America? These are questions that we want students to consider in this planetarium program.

The program encourages students to come aboard for a fascinating journey into the past. While on this journey, they will enjoy finding answers to the questions:

- What did Columbus actually do and why did he think he had found the Indies?
- How did Europeans of 1492 use compasses and quadrants to navigate, and how could they determine their latitude and longitude by observing the sky?
- Which groups of people explored and settled the Americas long ago?
- What does it mean to discover something?

We hope to leave the students with a richer understanding of: ocean voyaging and navigation, the social and economic state of the world in 1492, a broader perspective on the exploration and settlement of the American continents, and a deeper understanding of what it means to "discover" something.

Here's a brief overview of the program.

Part 1. Christopher Columbus and His Plan

Washington Irving's book *The Life and Voyages of Christopher Columbus*, published in 1884, was the source for most of the modern legend and textbook accounts of Columbus. Following publication of this book, Columbus Day became a national holiday in the United States. This program explodes some of those fables.

Your students find that it was untrue that Columbus insisted that the Earth is shaped like a ball, while the Queen's Counselors thought it to be flat. In fact, the Queen's Counselors had a fairly accurate understanding of the size and shape of the Earth. Columbus argued that the Earth was much smaller than it is, and that a trip from Europe to the Indies across the single Ocean Sea would not take very long at all — only about a month. Columbus's erroneous ideas about the size of the Earth led him to believe that the islands of the Carribean were actually somewhere near China and Japan. This was a misconception that he never corrected, even though he made four voyages to this part of the world.

These more realistic views of Columbus are a result of more careful examination of historical records carried out by authors such as Admiral Samuel Eliot Morison, who wrote a biography of Columbus entitled *Admiral of the Ocean Sea* in the 1940s.

This section also addresses social and economic issues not often covered by textbooks. Momentous events were recorded by a small number of eye witnesses. According to Columbus's own log, he and other European colonists who followed him treated the Native peoples very cruelly. The Europeans forced the Native peoples to mine gold. They captured hundreds and shipped them to Europe to be sold as slaves. They killed many Native peoples outright. The treatment of Native Americans by Columbus and other Europeans is briefly described at several points in the script for this program, and graphically illustrated. Columbus's voyages to the Americas set in motion a series of massive global changes, which continue today.

Part 2. Sailing with Columbus

The science of navigation as practiced by Europeans of Columbus’s time is the central hands-on activity in this part. Students learn how Columbus adopted the compass, a Chinese invention, to navigate the great Ocean Sea. They learn about how a compass points to magnetic north, and how it can be adjusted, using the stars, to point to true north. They use a quadrant to measure the altitude angle of the North Star to determine their latitude on Earth. With all these navigational techniques, the students are ready to “sail” with Columbus, across the Ocean Sea.

Part 3. Exploring the Americas

Students join Columbus on his fourth voyage to the Americas. They learn more about his treatment of Native peoples from his own log and from writings of eyewitness reports of that journey. They become shipwrecked with Columbus on a “mystery island.” They observe an eclipse of the moon and find out how Columbus used an eclipse to determine how far west of Spain his ship had landed. It becomes clear to them why Columbus died believing that he had come to the Indies, when they compare the location of the mystery island on Columbus’s map with its location on a modern map.

Part 4. Earlier Discoverers of America

Columbus was not the only explorer to arrive in the Americas. *Who “Discovered” America?* considers the evidence of other explorers who came to the Americas, including the most ancient explorers of all, the ancestors of today’s Native Americans. Finally, your students are asked to again consider the difficult question, *Who “Discovered” America?* Perhaps they will reach the conclusion that there is no definitive answer, no single discoverer. The Americas are here to be discovered anew by each person who visits this land, and each child who is born here.

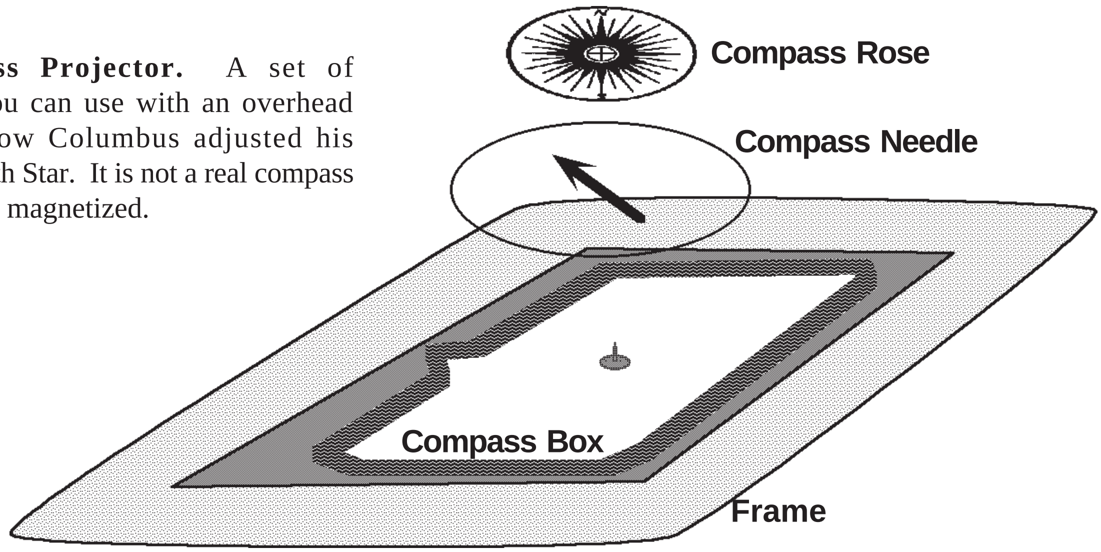
Objectives

After this planetarium program, the students will be able to:

1. Describe a few different meanings of the word *discovery*.
2. Tell how navigators adjusted their compasses by observing the North Star.
3. Use a quadrant to measure the altitude angle of the North Star to determine latitude.
4. Explain how observations of a celestial event, such as a lunar eclipse, can be used to determine how far east or west one is on the Earth.
5. Recognize prevalent misconceptions concerning Columbus, such as the idea that he proved the world is round, and the impression that he treated the natives with kindness and respect.
6. Name a number of other explorers who “discovered” America well before the time of Columbus.

Materials

1. A Box Compass Projector. A set of transparencies that you can use with an overhead projector to show how Columbus adjusted his compass using the North Star. It is not a real compass since the needle is not magnetized.



- ❁ Use a photocopy machine to make one transparency each of the compass rose, needle, and box, using masters on pages 4–5.
- ❁ Use a file folder or cardboard to make a frame large enough to cover the surface of the overhead projector, even when turned in a circle. Cut out the center of the frame and tape the box transparency to it.
- ❁ Cut out the needle circle and the rose circle from the transparency.
- ❁ Using a pushpin or thumb tack, pierce the box, needle, and rose transparencies on the “x” at the center of each object.
- ❁ Using a small nail (or larger thumbtack), enlarge the holes in the rose transparency and the box transparency so that they will be loose on the center pivot.
- ❁ Make the center pivot by inserting a thumb tack through center hole from the bottom of the box transparency, and securing it with a small piece of transparent tape.
- ❁ Place the needle and rose circles over the pivot as shown above.
- ❁ Practice using the compass projector by reading the section on pages 17–19 where it is used in the program.

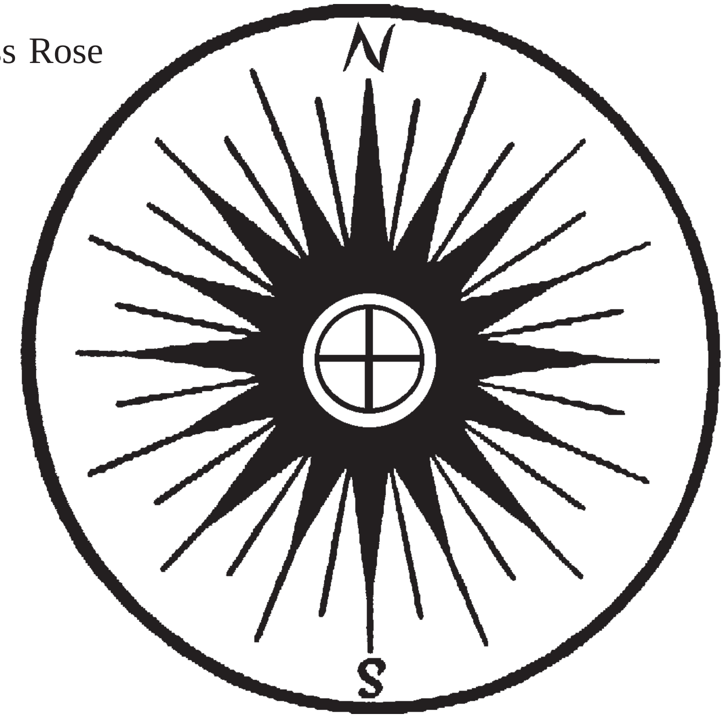
Optional Transparent Compass

You may wish to demonstrate a modern compass to show the deflection of the needle caused by a small magnet. Compass needles respond to the small magnet just as they do to the giant magnet—the Earth. You can use a regular compass and pass it around the room with a magnet for students to experiment with. Or, you can obtain a transparent compass to show on the overhead projector. Modern transparent magnetic compasses for classroom demonstration on the overhead projector are available from many sources. Two vendors are:

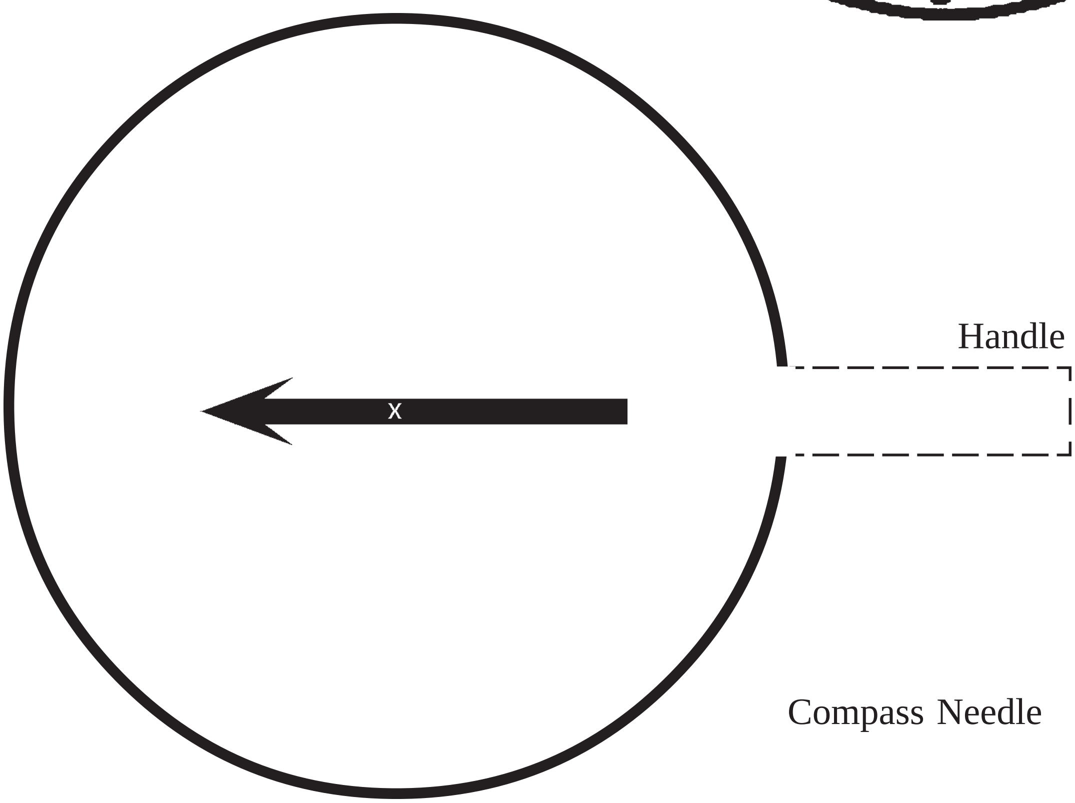
Frey Scientific
905 Hickory Lane
P.O. Box 8101
Mansfield,
OH 44901-8101
800-225-FREY
or 419-589-1522

Sargent Welch
7350 N. Linder Ave.
P. O. Box 1026
Skokie, IL 60076-1026
800-SARGENT
or 312-677-0624

Compass Rose

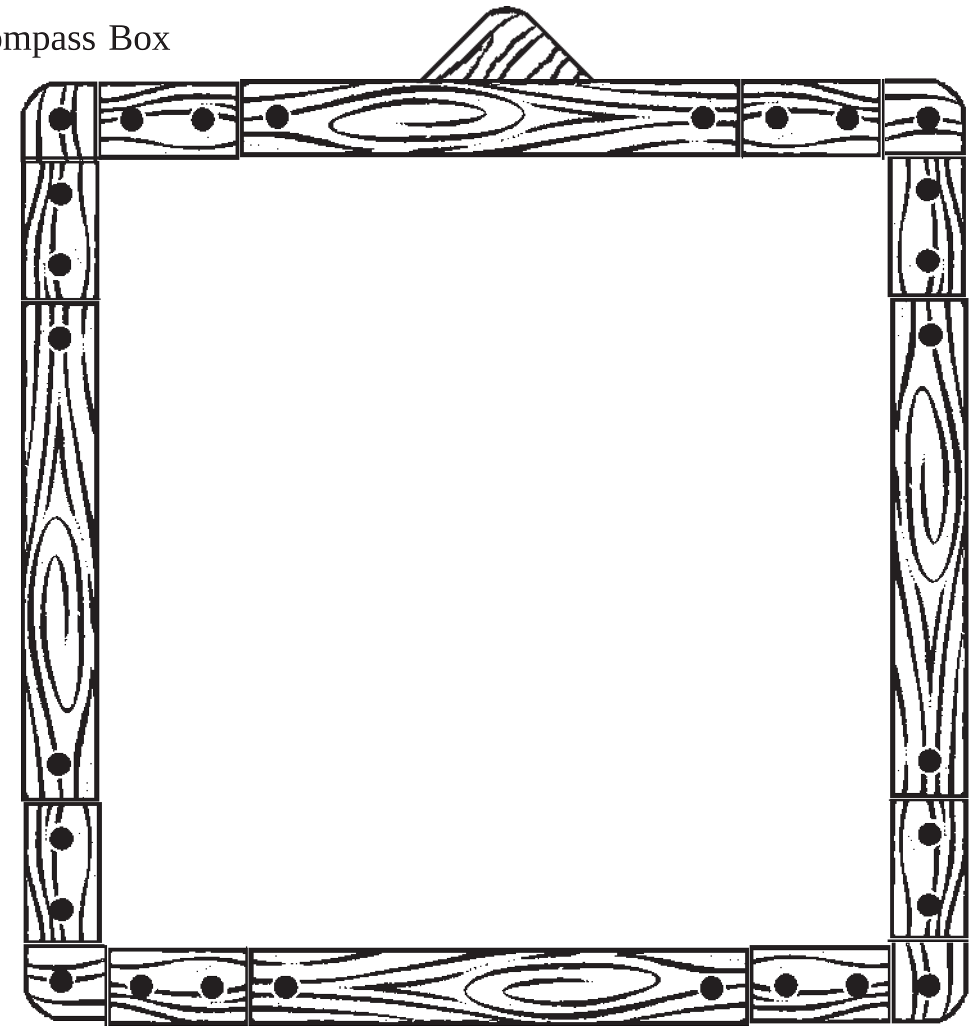


Handle



Compass Needle

Compass Box



2. Small Quadrants.

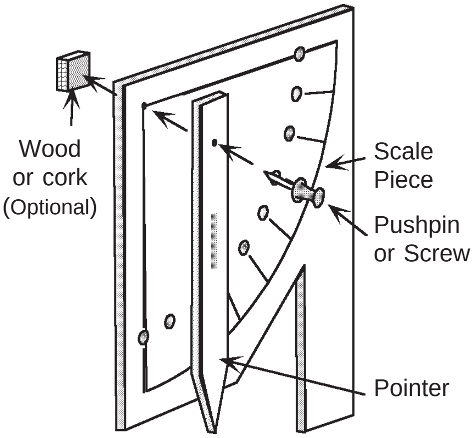
Use the quadrant pattern on page 6 to make a small quadrant for each student. For the most durable quadrants:

- Photocopy the pattern and glue it onto stiff cardboard. An easy way to do this is to photocopy the pattern onto adhesive label stock which can be bought at office supply stores in full-sheet-size labels (8 1/2"x11"). If you expect to use the quadrants many times, you may wish to use thin plywood or masonite instead of cardboard.
- Using either heavy duty scissors for cardboard, or a saw for wood, cut out the two pieces of the pattern for the scale piece and the pointer piece. For greater durability, cover each piece with transparent adhesive plastic, available at art stores or hardware stores.
- Punch or drill a hole in each piece at the spot marked “Push Pin” and fasten them together with a pushpin, rivet, small nut and bolt, or small screw. The pointer piece must swing freely, so the hole in it must be slightly larger than the diameter of your fastening hardware.

3. A pencil and clipboard. 1 for each student.

Who "Discovered" America — "Do-It-Yourself" Quadrant

for measuring the altitude of Polaris



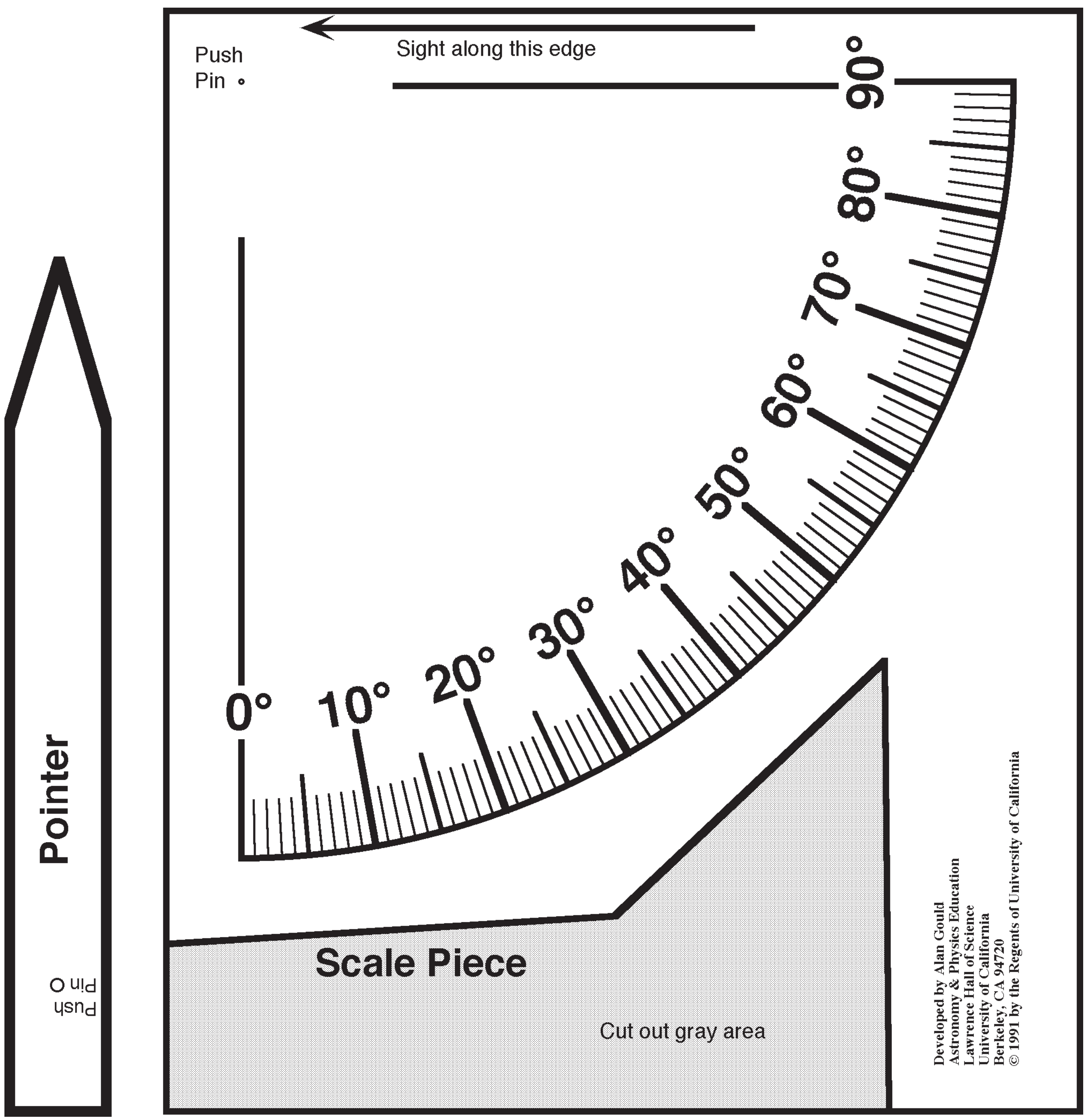
Instructions:

• Glue this sheet onto cardboard. Cut out the scale piece, the pointer and the gray area.

• Make a pushpin hole in the pointer at the indicated spot. Enlarge the hole with a pencil tip so that the point will hang loosely on the pushpin.

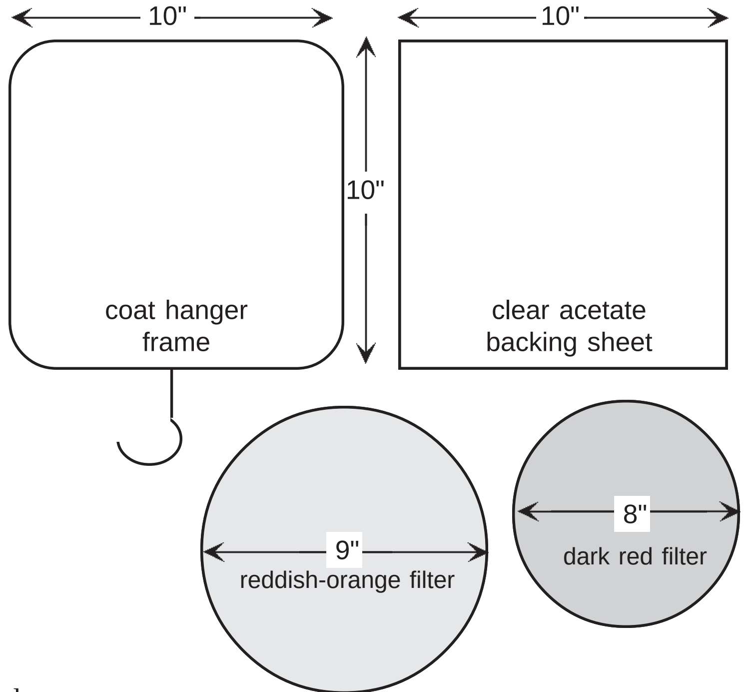
• Insert a pushpin through the pointer piece, then through the scale piece, and into a small piece of cork, soft wood, or pencil eraser tip. Make sure that the pointer hangs loosely.

• To use, sight on Polaris along the top edge of the scale piece, then press the pointer against the scale piece. Hold the pointer in place and read the altititude angle.



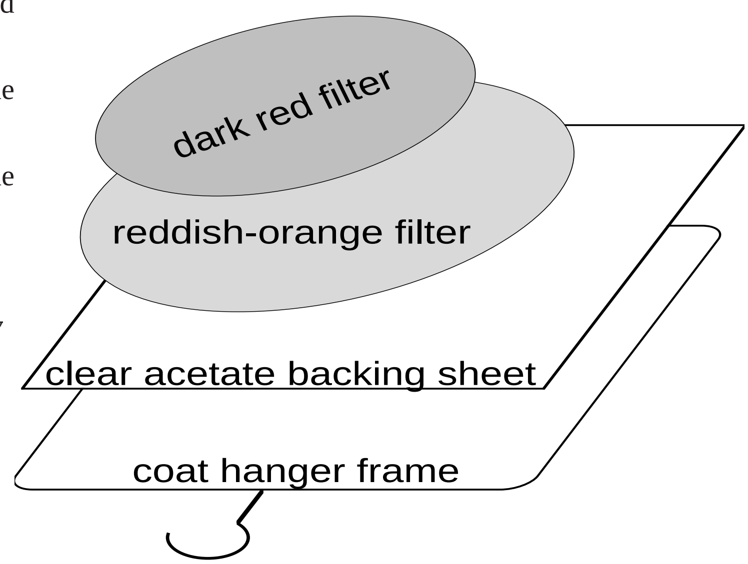
4. Lunar Eclipse Projector. If your planetarium doesn't already own one, or can't afford a commercially made unit, you can make a simple lunar eclipse projector with the following materials:

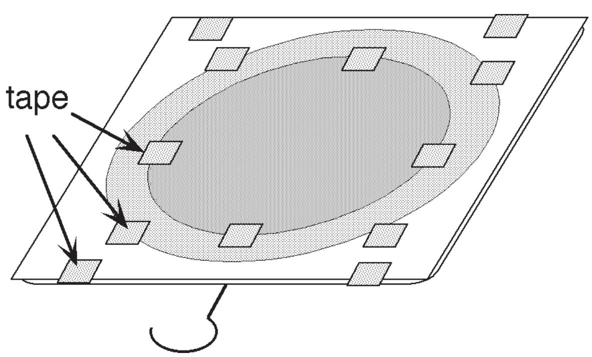
- ❑ slide of full moon; you can use slide #32 of the slide set for this program
- ❑ 2 sheets of transparent colored acetate, about 10" x 10": one dark red and one deep reddish-orange (available at art or theater lighting supply stores)
- ❑ 1 sheet of clear acetate 10" x 10"
- ❑ 1 heavy-duty wire (coat hanger is OK) bent into a 10" x 10" frame
- ❑ 1 roll transparent tape



To make the eclipse projector:

- Cut the colored filters to the sizes illustrated here.
- With transparent tape mount the layers in the order shown.
- Attach the clear acetate backing sheet to the coat hanger frame with transparent tape.
- The final filter will look like this.

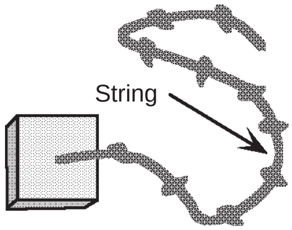




To operate the eclipse projector, darken the room. Project the full moon slide. Slowly move the filter through the beam of light about 6" to 8" in front of the slide projector so that the Moon gets red on the left-hand side first. You may wish to have a student sit below the projector and be the "eclipse maker."

The colored filter will be out of focus. This helps make it look real, because the shadow of the Earth is not sharp edged, although it is always round. It will be difficult for your students to determine exactly when the eclipse starts and ends, which is also like a real lunar eclipse.

5. **Kamals.** 1 for each student. The kamal is the Phoenician/North African device for measuring the altitude angle of Polaris in navigation. It is a square of wood or heavy cardboard (about 3" x 3") with a string or light rope tied to its center. The string has knots tied about every 2 inches.



6. **Pointer.** You will need at least one portable light pointer.

7. **Handouts.** 1 photocopy of each handout for each student, either single-sided or two-sided (masters on pp. 10–11):

"Columbus's World Map"

and

"Who Discovered America?"

8. **Music.**

(a) *Music from the Time of Columbus*, by Triangulum Musicum or other music from fifteenth century Spain.

(b) Ocean sounds: we suggest *Wood-Masted Sail Boats, #3* from Environments Cassettes ($9–$10, retail), or a similar "natural sounds" recording.

---

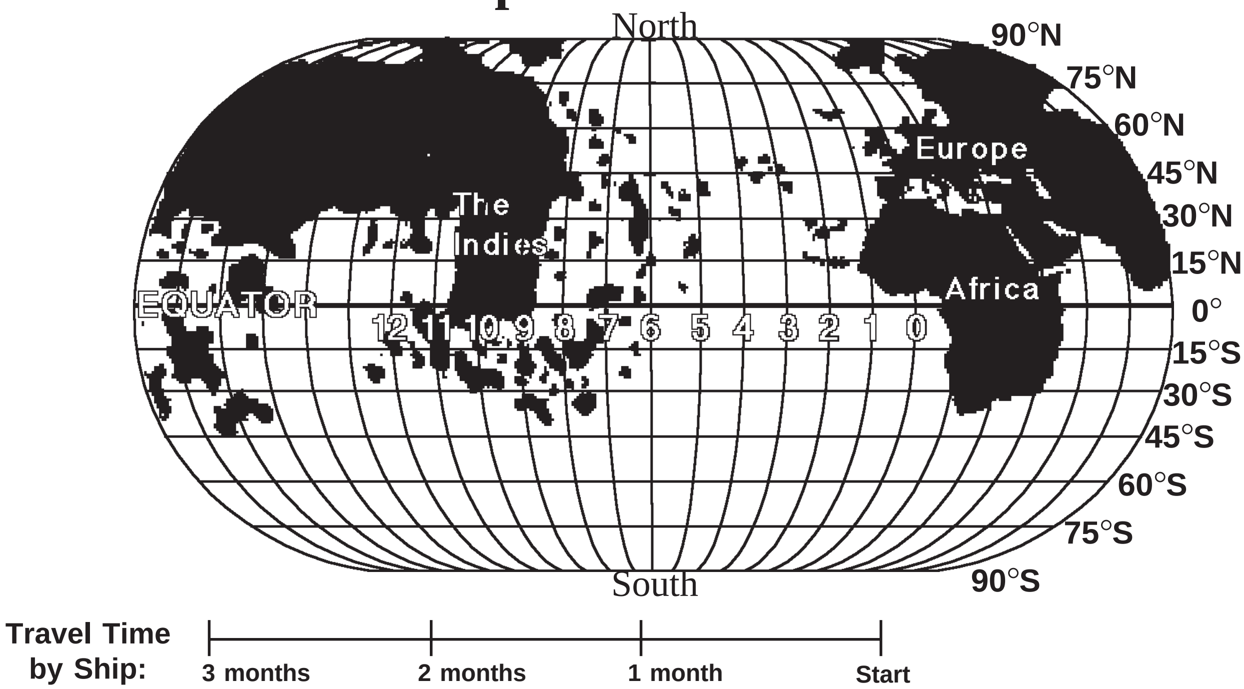
9. Images

	Image	Source
1.	"Who 'Discovered' America?"	LHS
2.	North and South America with sites marked	LHS
3.	American landscape	Dearborn
4.	Archaeologists at Calico Hills excavation	Calico
5.	Native Americans	Miguelena
6.	Ancient Observatory	Boice
7.	Dresden Codex	Hansen
8.	African Ship	Steerman
9.	Olmec stone head	Hansen
9a.	Genoa today	Bergami
10.	Japanese temple of gold	Sneider
11.	Columbus's world map showing routes from Portugal	LHS
12.	Columbus's world map with Columbus's route	LHS
13.	Land rising as ship approaches an island	NGS: Peter Lloyd
14.	Arguments at Salamanca	Sneider
15.	Ship like Columbus's	Sneider
16.	Box Compass	Sneider

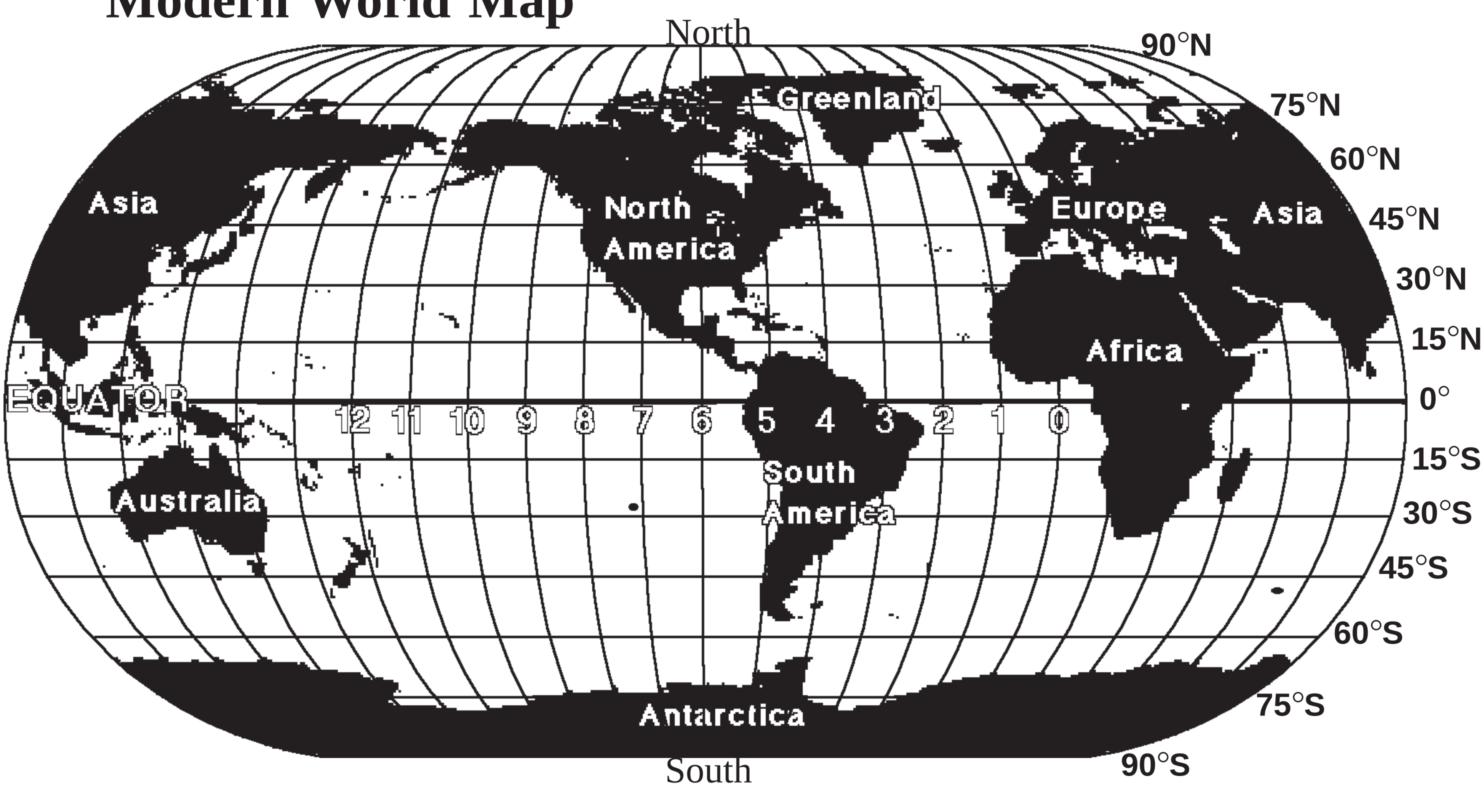
17. Modern World Map with latitude shown .... LHS
18. Brutality .... Las Casas
19. Modern world map with hours marked on equator .... LHS
20. Columbus's world map with latitude and longitude marked ..... LHS
21. Modern world map with latitude and longitude marked .... LHS
22. World map with Columbus's route to the Americas .... LHS
23. Vikings .... NGS: Library of Congress
24. World map with Leif Ericsson's route marked .... LHS
25. St. Brendan in a boat .... NGS: U. of Heidleberg
26. World map with St. Brendan's route marked .... LHS
27. World map with Asian route marked .... LHS
28. World map with African route marked .... LHS
29. Columbus at Spanish court .... Sneider
30. Hupa girls .... Miguelena
31. Credits .... LHS
32. Full Moon .... Lick

Calico:	Ruth Simpson and Don Lanz, San Bernardino County Museum, San Bernadinao, CA
Bergami:	Georgio Bergami, Publifoto, Genova, Italy
Boice:	Nancee Boice, San Lorenzo, CA
Dearborn:	David Dearborn, Lawrence Berkeley National Laboratory, Univ. of California, Berkeley, CA
Hansen:	Hansen Planetarium, Salt Lake City, UT
LHS:	Lawrence Hall of Science, University of California, Berkeley, CA
Lick:	Lick Observatory, Mount Hamilton, University of California, Santa Cruz, CA
NGS:	Nancy Beers and Ceres Bainbridge, National Geographic Society, Washington, DC
Miguelena:	Ralph Miguelena, Hoopa Tribal Museum, Hoopa Valley, CA
Sneider:	Cary Sneider, Lawrence Hall of Science, University of California, Berkeley, CA
Steerman:	Gregory Steerman, Lawrence Hall of Science, University of California, Berkeley, CA

Columbus's World Map



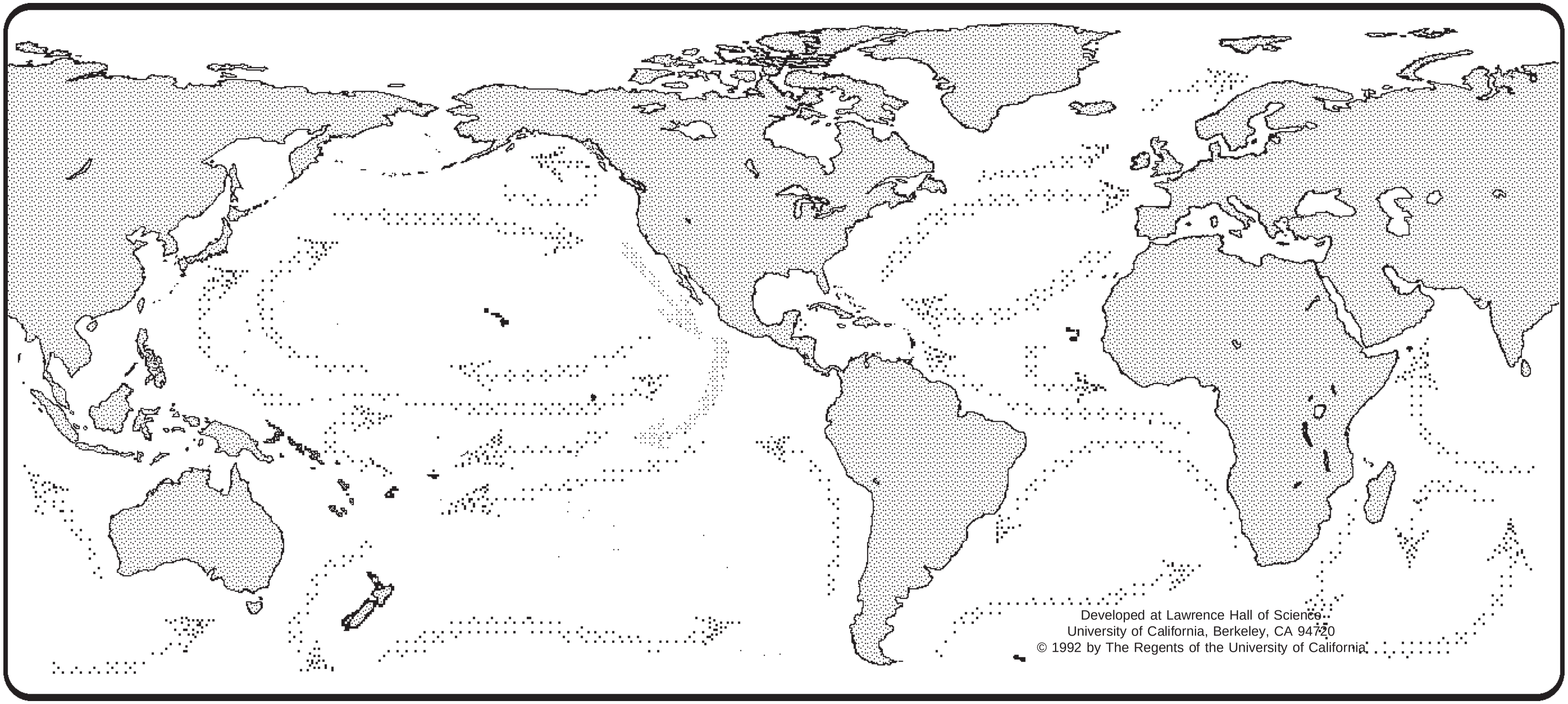
Modern World Map



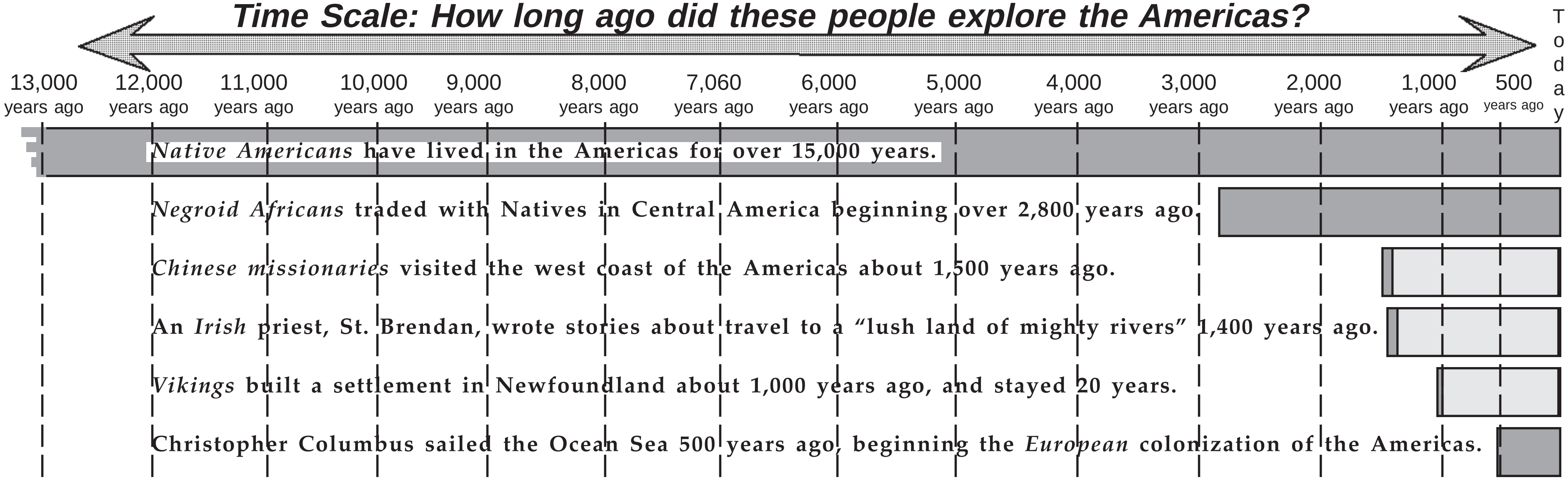
Record Latitudes Here:

Spain: ______ **Canary Islands:** ______ **Mystery Island:** ______

Who “Discovered” America?



Time Scale: How long ago did these people explore the Americas?



Setup

1. Set the moon as an almost full Moon.
2. Place the sun at sunset position on the western horizon.
3. Set up blue dome lighting for people to enter the dome.
4. Turn on side projectors on title, "Who 'Discovered' America?"
5. Setup and test special effect projectors :
   a. compass rose special effects projector
   b. lunar eclipse projector
6. Latitude: 36° North at beginning of program in Cadiz, Spain; then 28° N in the Canary Islands; and, finally, 18° N on the mystery island (Jamaica)
7. Check functioning of the portable light pointer(s).
8. Have ready a quadrant and handout for each student.
9. Slides may be used to suit your particular planetarium. There are no cross fading sets of slides or panorama projections required.

Recommendations for Using the Script

We don't expect the script that follows to be memorized as an actor might memorize a part. Use it as a guide in learning, rehearsing, and improving presentations. We recommend that you read the script once or twice; then work with it in the planetarium, practicing the projector controls, slides, special effects, and music. You should be able to imagine yourself presenting information, asking questions, and responding to participants. For your first few presentations, you may want to have the script on hand, using major headings as reminders of what to do next.

The script is organized in blocks or sections. The purpose of these separations is only to help you learn and remember what comes next. Once you have begun a section, the slides or special effects and your own train of thought will keep you on track.

Directions for the instructor are printed in italics, the instructor's narrative is printed in regular type, and ***directions and questions to which the students are expected to respond are printed in bold italics.*** There is no point in memorizing narration word-for-word, since what you need to say will depend upon the students. The language you use and the number and kinds of questions you ask will depend on how old the students are, how willing they are to respond, and how easily they seem to understand what is going on.

We believe the most important elements of the program are the questions and the activities, since these involve the students in active learning. If you must shorten your presentation, we recommend that you borrow time from the narration.

Script: Who "Discovered" America?

Introduction

Music: Walk-in music.

Image 1: Title Slide

Welcome. My name is ______________ and I would like to welcome you to the ____________ Planetarium. Today we ask the question, "Who 'discovered' America?" A simple question, but you may come to find it not so easy to answer.

Who do you think discovered America? *(Take several different suggestions and respond briefly as appropriate.)* Those are all good answers. In this program, we'll find out more about various people who are said to have "discovered" America, and what techniques they used to find their way here.

Image 2: Map of Americas

You should remember that the Americas include North, South and Central America. All of the "discoverers" of America found a huge, and beautiful land.

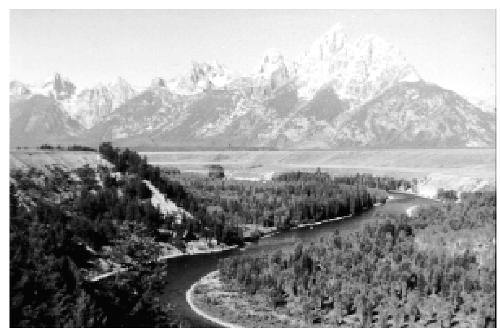
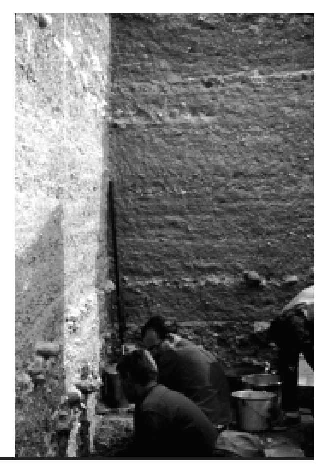


Image 3: South American Landscape

We do not know when people first found this land, but there is evidence that humans have lived here for a very long time.

Image 4: Archaeologist at Calico Hills excavation



This archaeological site at Calico Hills in southern California has shown that Native Americans lived here over 12,000 years ago. We find old burial sites and spear points embedded in skeletons of giant bison and mammoths. Scraping tools and stone knives are found at numerous ancient campsites throughout North America. Were those people the true discoverers of America?

There were many different people throughout this land by the time Christopher Columbus arrived 500 years ago.

Image 5: Native Americans

Native peoples had developed a close connection with the Earth.

Image 6: Ancient Observatories

They had developed a close connection with the heavens as well. A number of ancient cultures in the Americas built impressive observatories that helped them understand their relationship to the Sun, Moon, planets and stars.

Image 7: Dresden Codex

Some of the cultures kept written records of their observations while others recorded them as part of an oral tradition.

Getting Sky Oriented

Create a sunset with the first stars of evening and a full Moon visible. Leave "light pollution" (cove lights) on.

Many people throughout the world have learned star patterns, told star stories, and used the stars to find directions. Where are you from? Pretend we're in your town. There's a lot of light pollution. Let's go back 1,000 years and see the sky the way Native Americans might have seen it.

Turn off light pollution.

Can you find the Big Dipper? *(Offer a pointer to a volunteer. Point out seven bright stars in the Big Dipper.)* ***Can you find the North Star?*** *(Point it out; show how to find it using pointer stars of the Big Dipper.)* The North Star is also called *Polaris*.

Navigating Tool — Your Hand

The North Star is an extremely valuable tool for explorers, because it is straight up from the north pole of the Earth and always shows us where north is. ***If this way is north, which way is south? East? West?*** *(Point out those directions.)* ***If the North Star is directly over the North Pole, where in the sky would you find the North Star if you were standing at the North Pole?*** *(Straight up.)* As you move southward from the North Pole, the North Star is seen lower and lower in the sky. If we take a journey south for several days, we see the North Star get lower and lower in the sky.

Turn daylight up and down rapidly to simulate days going by, and move the latitude south by a few degrees so that its movement is noticeable.

Where would the North Star appear in the sky if you were at the equator? *(On the horizon.)*

If we travel northward, will Polaris appear to get higher or lower in the sky? *(Higher.)* You can use your hands to measure the height of Polaris. ***Try it.***

Demonstrate how to hold hands or fists to make a measurement of the altitude of Polaris. Any way of doing this is fine, as long as you do it the same way every time.

Let's make a journey of many days. See if you can tell if we have traveled north toward Canada or south toward Mexico.

Turn daylight up and down rapidly to simulate days going by. Move latitude south to about 30° N.

Measure Polaris again with your hand. ***Have we gone toward Canada or Mexico****? (Mexico.)* Just by using their hands, explorers can tell roughly how far north or south they have traveled.

Navigating Tool — The Kamal

Many ancient cultures devised ingenious ways to navigate and find their way in their desire to explore and trade with other peoples in the world. In the process of trading, these navigation techniques were also traded.

Image 8: African ships

Archaeological evidence suggests that around 2,800 years ago African sea-roving traders may have sailed to present-day southeastern Mexico, the home of the Olmec people. That's over 2,000 years before Columbus made his famous voyages. Olmec culture is probably the oldest of the great Central and South American civilizations.

Image 9: Olmec stone head

Olmec artists carved massive stone sculptures that appear to show a person with African features, wearing a distinctly African style headdress. The sculptures are found at a number of sacred sites in southeast Mexico where the giant heads were erected. When European explorers arrived much later, they were told of dark-skinned people living to the south. Metal alloys that the natives used for spear points were previously found in Africa. The exchange must have been both ways, since plants such as tobacco and corn were found in Africa but originated in America.

The kamal is an ancient tool used by Arab traders. It is likely that northern African sailors also used the kamal to tell how far north or south they had traveled. Let's see how sailors may have used the kamal. Pretend we are near the big port city of Algiers in northern Africa.

Play ocean sounds. Hand out kamals, and show how they are used to measure the altitude of Polaris.

Hold the wood block of your kamal so that its bottom edge lines up with the horizon and its top edge lines up with Polaris. The block has to be a certain distance from your eye to have the top and bottom edges on Polaris and the horizon. Holding the block in that position, extend the rope to your chin. The rope's knot that is closest to your chin is the knot for your home port of Algiers. Remember which knot that is by counting the knots from one end of the rope. Each other knot is the length of rope that would be our Polaris marker for other port cities where we might go.

If the Kamal block is moved closer to your eye, would that make the Polaris mark higher or lower in the sky? *(Higher.)* ***Would that be for a port farther north or farther south than Algiers?*** *(Farther north.)* Let's go on a journey from Africa west to the Americas. Make sure you remember which knot is for Algiers.

Raise and lower daylight several times while lowering latitude to 15°N.

We have sailed over 4000 miles west from Africa to Central America. ***Now use your kamal to see if we are farther north or south from where we were in Africa.*** *(Farther south.)* We are in southeastern Mexico where African traders may have landed 2,000 years before Columbus. We do not really know how they navigated, but they may have used an instrument like the kamal to find how far north or south they had traveled.

Optional: Go on another journey back to Algiers. Move latitude back towards the north, and have the students use their kamals to tell you when you have returned to the right mark for the home port of Algiers.

Navigating Tool — The Compass

The North Star is good for telling navigators which way north is on clear nights. But to find your directions in the daytime or on cloudy nights, you need another device that was invented in China over a thousand years before Columbus made his famous voyages. ***Do you know what that device was?*** *(Compass.)* ***Have you ever used a compass?*** *(Take responses.)*

About 1,530 years ago, a Chinese Buddhist priest named Hwui Shan and his company of missionaries sailed northeast to the Aleutian Islands and Alaska. He then followed the Pacific Coast of the Americas, calling it *Fusang*, which means "Fabulous."

Hwui Shan may have traveled as far south as Mexico. Details of his forty-year journey are found in the Chinese Imperial Archives. In his report to the Emperor, Hwui Shan described in detail the lands and people he saw. Many of the descriptions closely match what archaeologists believe the Americas were like at that time.

The compass has been used by the Chinese for navigation since its invention many centuries ago.

Optional demonstration: Show a modern transparent compass on overhead projector. Use a magnet to show how it attracts the compass needle. Remove the permanent magnet and turn the compass to show how the needle always points towards magnetic north—aligning itself with the Earth's magnetic field.

Let's see how the compass works. Let's imagine that we are in ancient China, navigating with a compass. On this overhead projector, I am going to make a demonstration compass so we can see how it works.

Sunset. Stars. Move latitude to about 36° N. Turn the compass projector on.

This is the box that holds the compass. It is attached to the ship. The triangular part indicates the prow, or front of the ship. It shows which way the ship is pointing.

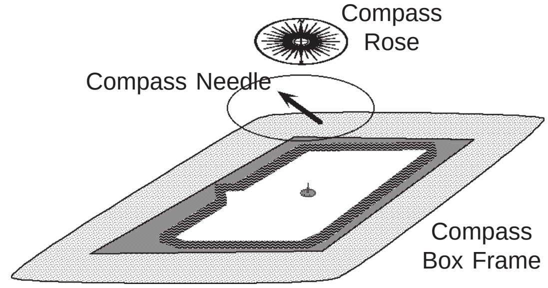
Demonstrate movement of box transparency (move by hand). Then add the Compass Needle layer. Demonstrate movement of compass needle (move it slightly by hand). Then adjust it so that it points about 15° to 20° away from the North Star.

This is a compass needle on the pivot at the center of the compass box. Ship's pilots all carried two or three lodestones, or natural magnets, used to magnetize a needle. The needle was placed on a pivot, so that it would stay flat as the ship rocked. If the ship turns, the compass needle still points in the same direction.

Demonstrate by holding the needle in place so that it points in the same direction while you pivot the box layer.

Does the needle point to the North Star? *(No.)* That's because the compass needle does not necessarily point true north. It points in a direction towards the North Pole, called "magnetic north." The difference between magnetic north and true north is not the same everywhere on the Earth. So, sailors needed to adjust their compasses to true north by the stars.

Place Compass Rose layer on the needle in some random orientation.



Here is a card, called a compass rose, that indicates the directions. We can adjust the compass rose so that it points true north, and then attach it to the top of the needle. This way, the compass rose always points to true north, even as the ship turns.

How do we find true north? *(North Star. Have someone point it out. If necessary review how to find the Big Dipper and North Star.)* The most accurate way to find north, east, south, and west is by using the North Star. Now we've found the North Star. Since the North Star is directly over the North Pole of the Earth, if we turn toward the North Star, we are facing directly north. ***Can you find east, south, and west, now that we know where true north is located?*** *(Invite responses.)*

Turn on N,E,S,W and point to them, or hang up NESW signs on your planetarium dome.

We need to adjust the rose so it points to true north. May I have a volunteer please?

Turn the compass back on. Show volunteer how to adjust rose so it points to the North Star. Hold the Box and Needle still while the student adjusts the Rose. The navigator has the best angle, so he or she is in charge. At other places in the planetarium, the needle may not appear to be quite aligned with the North Star. Another visitor can come up to check the navigator's alignment.

If the ship turns, the compass rose still points toward north. This pointer on the box shows us the direction the ship is sailing.

Turn box layer with one hand. Keep needle and rose from moving with your other hand.

Let's start sailing eastward from China. ***Is our ship headed eastward?*** *(Take group suggestions for correct adjustment of box.)*

Ocean sounds. Turn daylight up and down a couple of times to indicate days going by. Secretly throw the compass needle off by 10° or more.

The difference between magnetic north and true north changes a little bit as we continue to sail hundreds of miles to the east. Every time the stars are out, we can check the compass to see if the rose is still pointing towards the North Star. We must adjust it, if it is off.

Have a student volunteer adjust the compass. Continue sailing for a few more days; secretly throw off the compass; and have other students come up to adjust the compass as desired.

Turn off compass.

Even with modern magnetic compasses, you need to know the angle between magnetic north and true north to use a compass successfully. It is called the *angle of deviation* and is shown on navigational maps. The angle of deviation is different for various locations on the Earth.

Columbus's Navigating Tools

Europeans learned how to use the compass that was invented in China. The Chinese inventions of paper and gunpowder were also useful to Europeans. Before the time of Columbus, European traders made long and tortuous overland journeys over thousands of miles to get to the Far East — China, India, Japan and Southeast Asia. Europeans grouped all these places into one region that they called the *Indies*. ***What kinds of goods did people in Europe want to get from the Indies?*** *(Take suggestions.)* They wanted many riches: spices, gold, and silk.

Image 9a: Genoa today

Columbus grew up in Genoa, Italy, which is still a thriving port city. Five hundred years ago, ships from Genoa and other European cities sailed throughout the Mediterranean Sea, as well as up and down the west coast of Africa. Nearly every ship's cargo included slaves. In those days, people of many different cultures and races were captured and sold as slaves. Not everyone believed that it was right to enslave people, but nearly all merchants participated in the international slave trade because it made them very wealthy.

Image 10: Japanese temple of gold

As a merchant, Columbus knew of great wealth in the Indies. He may have heard about this temple, which is entirely covered with gold leaf. The temple is in the country Columbus called Cipangu, which we now know as Japan. The cost of silk and spices from the Indies was high, because of the difficult overland journey, and the goods were taxed heavily by the people who lived along the route. If Columbus could find a sea route to the Indies, he could avoid the taxes and sell his goods at a much greater profit. He could become the richest merchant of all!

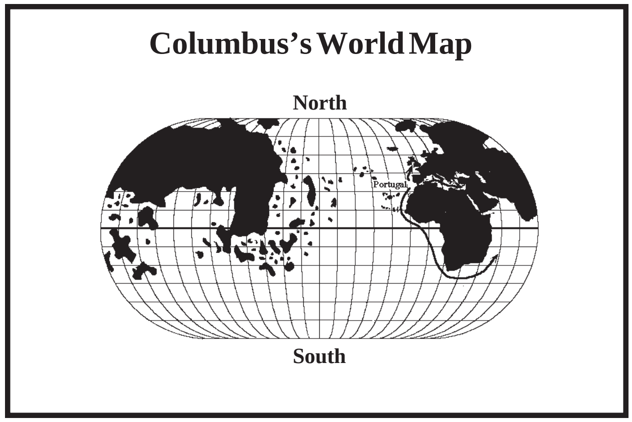


Image 11: Columbus's World Map showing routes from Portugal

In 1488, the Portuguese captain Bartholomew Dias made a voyage in which he rounded the southern tip of Africa and sailed along its eastern coast toward the Indies.

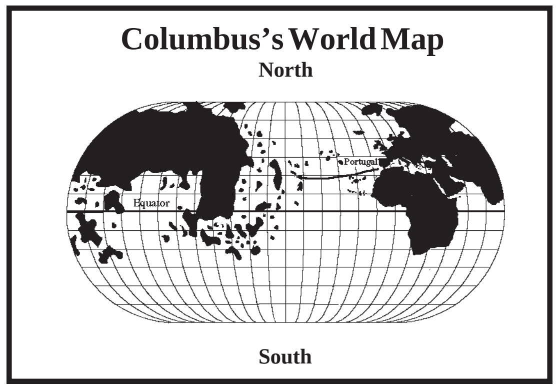


Image 12: Columbus's World Map showing his plan

But Columbus had another plan. He wanted to sail west across the great Ocean Sea to reach the Indies.

It is often said that Columbus wanted to prove the Earth was round.

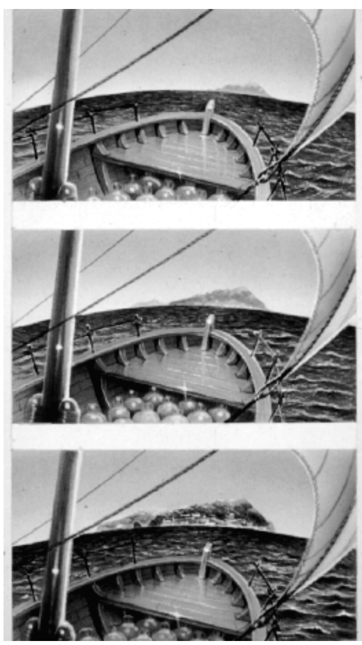


Image 13: Land rising as ship approaches

But Columbus was a sailor; and like all sailors of his time, he already knew the Earth was round. He knew because he had seen islands appear to rise from the ocean as he sailed toward them. On a flat Earth, this would not happen. All sailors knew that the Earth was round.

Optional: He had also seen the Sun and Moon in the sky, as you can see them. ***What shape are the Moon and Sun?*** *(Round.)* Many people reasoned that the Earth was also round because when you see an eclipse of the Moon, as we will see later, the shadow of the Earth on the Moon is always round. Only a "ball–shaped" Earth will always make a round shadow on the Moon during an eclipse.

Other evidence that the Earth is round was found by comparing the length of the shadow of a stick at noon in various locations many miles directly north or south of each other. The lengths of the shadows are different.

Columbus tried to convince the kings and queens of England, France, and Spain to finance his journey, but failed many times. This is mainly due to the fact that his plan called for sailing west into relatively unfamiliar waters rather than along safer coastal routes. ***Do you know who finally supported Columbus's plan to sail west across the Ocean Sea?*** *(King Ferdinand and Queen Isabella of Spain.)*

Image 14: Arguments at Salamanca

Before the King and Queen would give him money for ships, supplies, and a crew, Columbus first had to go to Spain's best university, in Salamanca, to convince its professors that his plan was practical. We see Columbus at Salamanca in this image. ***What shape is the model of the Earth is this image?*** *(Round.)* You may have heard that Columbus proved that the Earth was round, but that is not what he did. In those days, all educated Europeans knew that the world was round. Columbus didn't need to prove it. Scholars had known this for over 1,800 years. So what did Columbus argue about with the professors? Let's look at some maps and see.

Distribute "Who 'Discovered' America?" handout, one to each student. If necessary, hand out pencils.

Please look at the side of the paper that says "Columbus's World Map" at the top. What is the difference between "Columbus's World Map" and the "Modern World Map"?

Allow time for students look at the maps and discuss their observations. Accept several answers.

The modern world map is larger. Columbus thought the Earth was only about 18,000 miles around, while professors at Salamanca argued that it was about 24,000 miles around: much closer to what geographers believe today. It was known that the trip from Europe to Asia by *land* was about 12,000 miles, so Columbus argued that most of the world was covered by land and "The Ocean Sea" was not very big. The professors argued that the Ocean Sea covered only about half of the world.

Using the time scale at the bottom of "Columbus's World Map," figure out how long it would take to cross the Ocean Sea on both maps. Who can tell me how long Columbus thought the voyage would take? *(About 1 month to the large island, which he thought was Japan.)* ***And, how long did the professors think the voyage would take?*** *(About 3 months, keeping in mind that they did not expect that the American continents intervened.)*

Image 15: Ship like Columbus's

This is a full–size replica of the ship that Columbus sailed in 1492. It is small. You would run out of food and water on a trip of more than one month. So Columbus was taking a big risk to sail across the Ocean Sea.

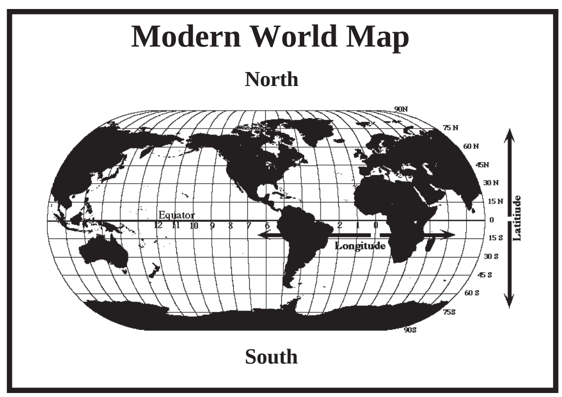
The money for the voyage came from the Spanish treasury. During this period known as the Inquisition, the treasury had been enriched by property confiscated from Moslems and Jews who were expelled from Spain.

Latitude and Longitude

Image 16: Box compass

Columbus used a compass like this one, which he adjusted by the North Star just as we did a little while ago in China. Columbus also used a device known as a ***quadrant*** to find his *latitude* from the North Star.

Image 17: Modern World Map with latitude and longitude shown.



Latitude is distance north or south of the equator measured in degrees. *(Point this out on the map.)* ***Longitude*** is the distance east or west from the Greenwich Meridian. The Greenwich Meridian is an imaginary line that goes from pole to pole through the city of Greenwich, England, and several European countries including Spain. Longitude can be measured in degrees, or in time zones as we see here. *(Point this out on the map.)*

A ***quadrant*** is a quarter of a circle**.** It is also the name of a navigational instrument that is shaped like a quarter of a circle, and marked in degrees. A whole circle has 360 degrees. A quarter of a circle, a quadrant, has 90 degrees. ***You can now use your quadrant to measure the angle between the North Star and the horizon.***

Distribute quadrants and explain how to hold them, sighting along the top edge. Explain that you use your free hand to "clamp" the pointer onto the scale on the quadrant, and then read the degrees on the scale. To help the students sight on the North Star, turn on the arrow that indicates the celestial North Pole.

Arabic and Chinese navigators also used tools similar to the quadrant used by Columbus.

Imagine you are at the North Pole and must look straight up to see the North Star. What would the reading on your quadrant be at the North Pole? Try it! *(90°.)* As you can see on your map, 90° is also the latitude of the North Pole.

Now imagine you are at the equator where you would see the North Star on the horizon. ***What would your quadrant read there?*** *(0°.)* 0° is the latitude of the equator. In between the equator and the North Pole, the height of the North Star will be in between 0° and 90° and the number of degrees is the same as our latitude.

Actually, Polaris is just under 1° from the true North Pole. Mariners have long known how to correct for this error, but it is probably too small to notice in the planetarium.

Can we still find the North Star? *(Point it out.)* Imagine that each of you, by sitting in a different place in the planetarium, are in a different location in the world Columbus knew well, either Europe or Africa. *(Alternatively, have students pretend that they are somewhere in the Americas.)* ***Now, let's all measure the altitude of the North Star.***

Allow students to report their measurements. Tell different groups of students what country they would be in for their particular measurement:

Raise your hand if your reading was between 60° and 70°.

60°–70°	*Norway*	*(or Alaska)*
50°–60°	*England*	*(or Canada)*
42°–50°	*France*	*(Oregon or Washington)*
36°–44°	*Spain, Italy*	*(or California)*
0°–36°	*Africa*	*(Southern California: 32°–36°)*
		(Mexico: 16°–32°)
		(Central America: 7°–16°)

Optional: Ask if anyone can explain the differences. (In the planetarium, we are not measuring the real North Star. If you go out at night to sight the real North Star, all your measurements would be very close to the same number. This is because the real North Star is extremely distant.)

Please find Spain on your "Columbus's World Map." What is the latitude of Spain? *(Anywhere from 35° to 44° shows that your students are reading the map correctly.)* In 1492, Columbus set sail from southern Spain which is about 36° north latitude. ***Please record the latitude of Spain as 36° N at the bottom of the page.***

First, he sailed south to the Canary Islands. As we sail south, days and nights and days go by.

Play ocean sounds. Show "days and nights passing" by raising and lowering daylight several times. Move latitude to about 28° N for the Canary Islands.

We have arrived at the Canary Islands. ***Please measure the altitude of the North Star again and tell me if it is higher or lower in the sky?*** *(Lower; we are farther south than Spain.)*

If your students are concerned that their measurements are all different from each other's, tell them that it is because they are not measuring the real North Star. The one in the planetarium is much too close. They should all agree, however, on whether or not the North Star is higher or lower than before.

Identify a student or group of students whose measurement was close to 28°.

At the Canary Islands Columbus measured the altitude of the North Star to be about 28° above the horizon just as these students. ***Let's record at the bottom of the page the latitude of the Canary Islands as 28° north.***

From the Canary Islands near Africa, Columbus sailed west across the great Ocean Sea.

Show "days and nights passing" by raising and lowering lights several times. Ocean sounds. Change latitude to about 18° north.

When they finally arrived at an island in what they thought were the Indies, Columbus and his men were treated very well by the native people called Tainos or Arawaks. Yet Columbus later forced these people to provide him with gold. He enslaved and killed many of those who had previously helped him.

Image 18: Brutality

This brutality was reported by some of Columbus's Spanish countrymen who felt that what Columbus did was wrong. This drawing was done by a Spanish priest named Bartolomé de Las Casas. It is based on what he saw on Hispaniola, the large island where Columbus built the first Spanish colony. Friar de Las Casas spent most of his life trying to stop the enslavement and murder of the Native Americans. Many textbooks have ignored this bit of history.

Columbus made four journeys to the Americas. On his third journey he was stranded for over a year on an island that we shall call Mystery Island. Let's see if we can figure out exactly where Columbus was. ***Please measure the altitude of the North Star again and tell me if it is higher or lower in the sky.***

Identify a student or group of students whose measurement was close to 18°, and announce that they got the same measurement as Columbus did on the mystery island.

Please look again at your "Columbus's World Map." Write the latitude of the mystery island: 18° N.

But how could Columbus tell how far west of Spain he was? Columbus estimated how far west he was by observing an eclipse of the Moon.

In order to understand how a lunar eclipse helped Columbus determine his longitude, you need to understand that people separated by large east-west distances see an event (such as an eclipse) at different times of day. ***Have you ever talked on the telephone to a friend or relative in a different time zone and asked them what time it was there? "How many time zones between New York and San Francisco?"*** (3 hours apart.)

Optional: Sunrise to Noon Activity

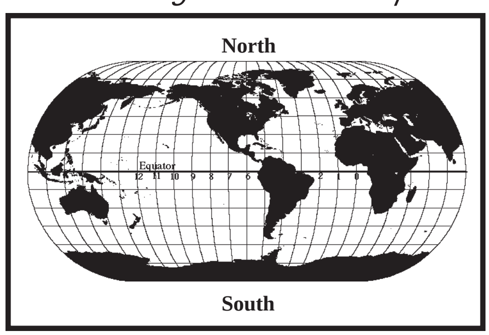
Have everyone stand up. Tell people in the east part of the planetarium that they are in New York. People in the west part of the planetarium are in California. People in between are in mountain or midwest states *(like Kansas)*.

Tell the students that you are speeding up time. Begin diurnal motion and have them watch the stars move until sunrise. Explain that during the day, the sun will not go straight overhead, but will sweep in a curved path towards the south. Continue diurnal movement, and have people call out "noon" when the Sun is most directly over them.

Did everyone say "noon" at the same time? *(No.)* ***Do people in California see the noontime Sun at the same time as people in New York?*** *(No, Californians see the noontime Sun about 3 hours after New Yorkers do.)* ***How about Spain?*** *(Even more time difference.)*

Suppose you were to pick up the telephone in San Francisco, California, and call Spain. If it is 12:00 noon here in the San Francisco Bay Area, the person in Spain says it is 8:00 p.m. ***How many time zones are you west of Spain?*** *(8)* ***Check it out on the "Modern World Map."***

Image 19: Modern World Map with hours marked on equator. Point to map to illustrate what the students are looking for on their maps.



Please look at your papers of the two world maps again. Notice the numbers along the equator. They are time zones. Altogether, the world is divided into 24 time zones just like the 24 hours in a day, one hour for each time zone.

How many of you have seen an eclipse of the Moon? *(Take a show of hands.)* Let's watch the eclipse from the beach where Columbus landed.

Ocean sounds. Operate the lunar eclipse projector.

Columbus records in his journal that he timed the ending of the eclipse to determine how far around the world he had traveled from Spain. Let's see how he did that, and how we can determine where in the world the mystery island is located. ***When you see the eclipse end, say "Now" out loud.***

Students say "Now" at different times as the eclipse ends.

We each saw the eclipse end at a little different time. It is hard to determine the exact time when an eclipse ends.

Columbus, on the mystery island, watched the same eclipse that the people in Spain watched. But the local time of night was earlier for Columbus than for the people in Spain. The time difference could tell Columbus how far west of Spain he was. Let's see how far west he thought he was.

Columbus recorded the time of an eclipse that people in Spain were also watching. Comparing his time record with those of his friends in Spain, he could find out how many time zones away from Spain he had traveled.

Do you think that Columbus just timed the lunar eclipse with a stopwatch and then telephoned his friends in Spain to ask them exactly what time their clocks said the eclipse ended in Spain? *(No. There were no stopwatches or telephones in Columbus's day.)* Columbus used big sand clocks, like giant egg timers, to measure the passage of hours. It was very difficult to determine exactly when an eclipse ended.

Columbus saw the eclipse end about 2 hours after sunset. He had a book that predicted the end of the eclipse would be seen in Spain 7 hours after sunset. ***What is the time difference between Spain and the mystery island?*** *(5 hours.)* The mystery island is about 5 time zones west of Spain.

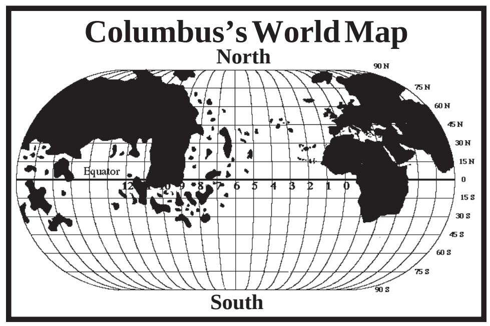
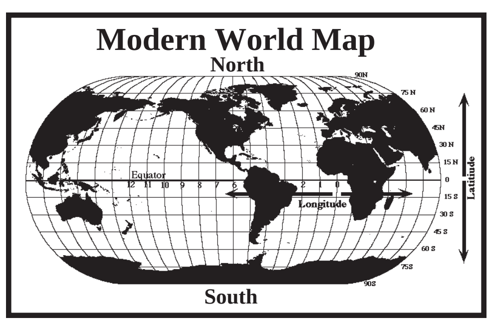


Image 20: Columbus's World Map with latitude & longitude

Let's see where that is on Columbus's World Map. First, let's count off the five hours west. *(Count with pointer on slide.)* ***Now, what is the latitude we measured earlier for the mystery island.*** That's 18° north of the equator. ***So, where in the world was Columbus?*** *(Point on projected map.)* About here, near the part of the world he thought was the Indies.

Image 21: Modern World Map with latitude and longitude.



Now, let's count off 5 time zones, and find out where Columbus was on the Modern World Map. Remember also that his latitude was 18° North. ***Does anyone know the name of the islands here?*** *(Point to slide.)* The small one where Columbus landed is Jamaica. The mystery island is really Jamaica!

Columbus returned to Spain believing that the islands he explored were very close to the Indies. This was because he had incorrect ideas about the size of the Earth and how much was covered by land. He never visited the land we call North America today.

Summary of Discoverers of America

Columbus was certainly not the first person to explore the Americas. There is a lot of evidence that many other people visited the land we call the Americas long before Columbus.

As we discuss these early visitors, think about "how" they discovered the Americas. What route did they take? Were they expecting to discover the Americas? Did they end up there by accident? Did they all explore the same America? What was their purpose? What was the impact of their discovery? How long did they stay?

Refer to the students' answers to the question "Who discovered America?" at the beginning of the program. For example: "You mentioned the Native Americans, and Leif Ericsson."

Let's look at Columbus.

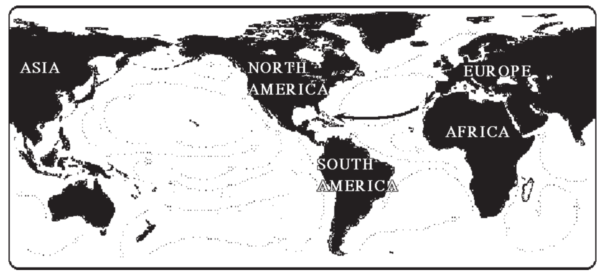


Image 22: World Map with Columbus's route to the Americas

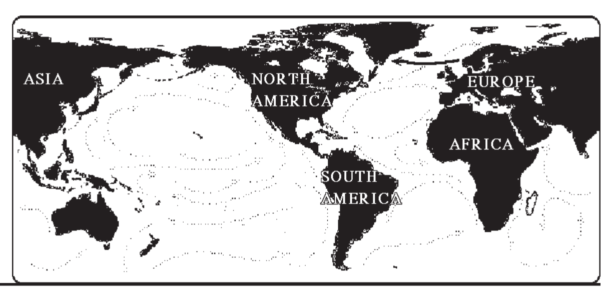
Please turn your paper over, and draw Columbus's route from Spain to the Americas. He heralded a great influx of European explorers that had a most extreme effect on the Americas. Yet Columbus never found the mainland of the Americas. He thought he had reached the Indies.

Image 23: Vikings

Vikings from different countries have told the same story about visits to North America. Two very old Icelandic-Norse sagas describe in clear, believable detail the exploration and settlement of North America about 1,000 years ago.

According to the sagas, the first Viking to sight North America was Bjärni Herjolfsson who was sailing from Iceland to Greenland during the summer of A.D. 986. Searching for new sources of timber, he was blown off his original course, and ended up in North America. Later, Leif Ericsson heard about this accident. He bought Herjolfsson's 76-foot ship and assembled a crew of 35. They set out from Greenland to find the land Herjolfsson described but did not explore.

Image 24: World Map with Leif Ericsson's route marked



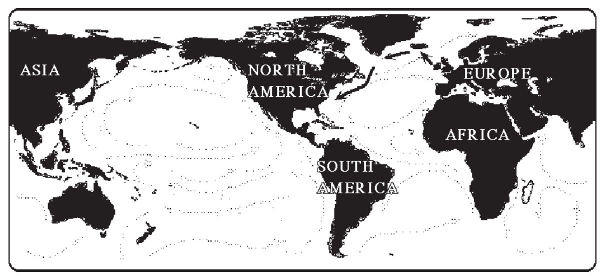
Sailing from Greenland, Ericsson explored the northern islands and coast of the Americas as far south as what we call Newfoundland. He built a camp for the winter. This campsite was probably the first European settlement in the Americas. Different Vikings lived there, off and on, for about 20 years. They were expelled by angry local Native Americans whom Vikings had mistreated. *(Vikings had somewhat of an image problem in other places as well.)* In recent times evidence of the Viking settlement has been found on the northeastern tip of Newfoundland.

Use your pencils to draw the route taken by Leif Ericsson to the Americas.

Image 25: St. Brendan in a boat

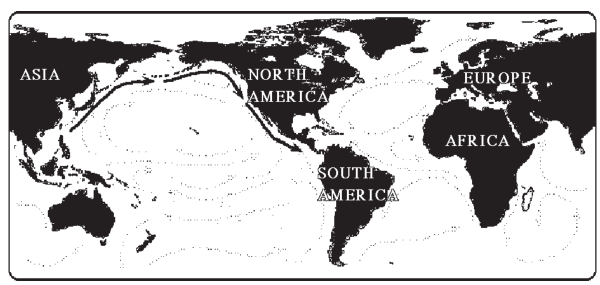
Sometimes we find hints of early voyages in other stories. An ancient Irish saga, the “Voyage of Saint Brendan, the Abbot,” describes a journey by ship made to a place called “The Land Promised to the Saints.” It was somewhere beyond the far reaches of the Western Atlantic.

According to this legend, St. Brendan and 17 fellow monks set sail from Ireland in a leather-hulled ship about 1,400 years ago. The entire voyage lasted seven years. The monks experienced things never before encountered, such as a floating crystal column. ***What could the floating crystal column be?*** *(It was probably an iceberg.)* St. Brendan also saw a sea creature as great as an island. ***What type of creature was that?*** *(Most likely, it was a whale.)*



Finally, St. Brendan and his shipmates reached a huge, lush island divided by a mighty river. They managed to sail back home to Ireland, where St. Brendan later died. ***Let’s look at the map. What route could St. Brendan have taken?*** *(Discuss and then show the image of St. Brendan’s route.)*

Image 26: World Map with St. Brendan’s Route marked



We really do not know the route St. Brendan sailed. It may have been like the one we see here. ***Let’s draw on our maps the route St. Brendan might have sailed.*** Very little evidence exists today to confirm that St. Brendan and company actually visited North America.

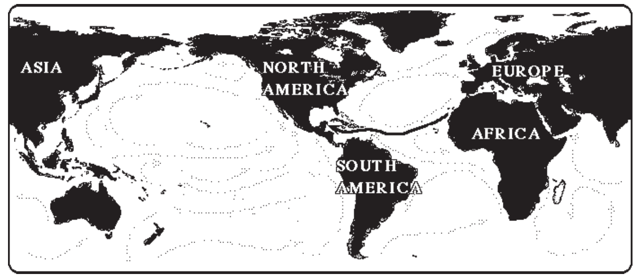
Remember the Chinese priest, Hwui Shan? He came to the west coast of the Americas over 1,500 years ago. ***What was his route to the Americas?***

Image 27: World Map with Asian route marked

Let’s draw the route from Asia to the Americas on the map. *(Students draw on their maps.)*

For safety, most of the explorers before Columbus traveled along coast lines, or from island to island, not directly across the oceans. But the people from Africa went directly across the Atlantic Ocean.

Image 28: World Map with African route marked



We think they sailed on the currents from Africa to Central America. ***Let's draw a route from Africa to the Americas on the map.*** *(Students draw on their maps.)*

All of these ocean-going explorers, from Ireland, Norway, China, and Africa, had one thing in common: they were met by people who already lived here in the Americas. We do not know how long humans have lived in the land we call the Americas. But we do know that 12,000 years ago there was a widespread Native American culture.

Today, their descendants are among the many people who are Americans. During the past several thousand years there must have been many "discoverers." They crossed the ocean or the land to explore new valleys and mountain ranges. They were the first people to settle in the forests and grasslands of the continents we now call the Americas. These are the people we call *Native Americans*.

Consequences of Discovery

Image 29: Columbus at Spanish court

Exploration by Columbus opened up a new world for the Europeans. From King Ferdinand and Queen Isabella's viewpoint, agreeing to fund Columbus's first voyage was an immensely successful business venture. Spain became one of the wealthiest nations in Europe due to its trade with colonies in the Americas.

At the same time, historical records show that in just a few years, millions of Native Americans were killed in raids or battles with the Europeans. Millions more died of European diseases for which they had no immunity.

In the decades that followed, Spain, Portugal, England, and France set up colonies in the Americas. Millions of slaves, primarily from Africa, were brought to provide labor on plantations, raising sugar, cotton, and tobacco. Native forests were cut down. European varieties of crops and methods of agriculture took over. In the past 500 years, almost all of the forests in North America have been cut down and replaced by today's cities and farms. The destruction of the remaining old growth forests continues even now throughout the Americas.

Conclusion

Let's reconsider the question. Who "discovered" America? ***What does* discover *really mean?*** *(Take answers and add from the list below any not provided by your students.)*

Discovery *means the first time a person sees something that has never been seen by anyone before. For example, the first person who observes and reports on a new comet is usually considered the "discoverer," and the comet is usually named after that person.*

Discovery *means the first person who recognizes the significance of something that others have seen before. For example, an archaeologist might be credited as the discoverer of ancient stone tools if she is the first to recognize the telltale marks of human industry on rock.*

Discovery *means the first time a person notices something that he or she has never seen before even though that place has probably been discovered by many people in the past. For example, a person might "discover" a wonderful spot to go fishing and tell a few friends about it.*

Discovery means "to make known." Certainly Columbus "made known" the "new world" to the people of Europe.

Discovery means different things to different discoverers. To Native Americans, it might mean learning more about the land to better live in harmony and adjust to its changes. To many of the European explorers, America was a place to conquer and control.

Can we really say that there was just one person who "discovered" America? What is your opinion? *(Take answers and encourage discussion.)*

There is no single, simple answer to the question: Who "discovered" America?

Image 30: Hupa girls

These are young Native Americans who now live in northern California. Like other Americans, they usually wear blue jeans or dresses; but today they are celebrating a holiday, so they are in ceremonial dress. Native people throughout the Americas are trying to maintain their culture and religion. Native people are still fighting to retain their dignity amongst many who have no understanding or respect for the way of life that has continued from ancestral times.

It is sad that throughout the history of the Americas, there has been bitter fighting, hatred, and mistrust among all its "discoverers." It is our sincere wish to learn a better, more peaceful way for all of us "discoverers" to live together in this magnificent land.

Image 31: credits

References

For latest updates and links, visit http://www.lhs.berkeley.edu/pass

Who "Discovered America?" is based on information and interpretations gleaned from the following sources:

Bahn, Paul, "Dating the First American," *New Scientist*, July 20, 1991.

Bianchi, Luciano G. and E. Poleggi, *Una Citta' Portuale Del Medioeva*, Genoa, Italy: Sagep Editrice, 1980.

Blaine, James G., J.W. Buel, John C. Ridpath, and Benj. Butterworth, *Columbus and Columbia, A Pictorial History of the Man and the Nation,* Seattle: Dominion Publishing Company, 1892.

Boorstein, Daniel J., *The Discoverers: A History of Man's Search to Know His World and Himself,* New York: Vintage Books, 1983.

Borzani, Giovanni, *Porti e Aeroporto di Genova,* Genova: Unione Stampa Periodica Italiana, 1978.

Brandon, William, *New Worlds for Old: Reports from the New World and Their Effect on the Development of Social Thought in Europe, 1500–1800,* Athens, Ohio, London: Ohio University Press, 1986.

Braudel, Fernand, *The Structures of Everyday Life: Civilization and Capitalism 15th–18th Century, Vol. 1: The Limits of the Possible,* New York: Harper and Row, Publishers, 1979, English translation copyright, 1981.

Braudel, Fernand, *The Mediterranean and the Mediterranean World in the Age of Philip II, Volumes 1 and 2,* New York: Harper and Row, Publishers, 1976.

Brown, Lloyd, A., *The Story of Maps,* New York: Dover Publications, Inc., 1949, 1977.

Brucker, Gene A., *Renaissance Florence,* New York: John Wiley & Sons, 1969.

Burke, James, *The Day the Universe Changed,* Boston: Little, Brown, and Co., 1985.

Cabona, Danilo, *Porto Di Genova,* Genoa, Italy: Sagep, 1986.

Chiappelli, Fredi, ed., *First Images of America: The Impact of the New World on the Old,* Co-editors: Michael J. B. Allen & Robert L. Benson, Berkeley: University of California Press, 1976.

Christian, William, *Local Religion in Sixteenth Century Spain,* Princeton: Princeton University Press, 1980.

Columbus, Christopher, *Four Voyages to the New World: Letters and Selected Documents,* trans. and ed. R. H. Major, Introduction by John E. Fagg, New York: Corinth Books, Inc., 1847, 1961.

Columbus, Christopher, *The Four Voyages of Columbus: A History in Eight Documents, Including Five by Christopher Columbus, in the Original Spanish, with English Translations,* two volumes bound as one, ed. Cecil Jane, New York: Dover Publications, Inc. 1930, 1988.

Cousins, Norman, *Why Man Explores?,* U.S.: NASA Educational Publications, 1976.

Deagan, Kathleen A., "Searching for Columbus's Lost Colony," *National Geographic*, November, 1987.

Dreyer, J. L. E., *A History of Astronomy from Thales to Kepler*, Dover Publications: New York, 1953.

Elliott, John H., *Imperial Spain 1469–1716,* New York: Meridian, 1963.

Elliott, John H., *The Old World and the New, 1492–1650.* Cambridge, England: Cambridge University Press, 1970, 1972.

Finney, Ben R. and Eric M. Jones, eds. *Interstellar Migration and the Human Experience,* Berkeley: University of California Press, 1985.

Fuson, Robert H., *The Log of Christopher Columbus,* International Marine Publishing Company, 1987.

Gerbi, Antonello, *The Dispute of the New World*, Pittsburgh: University of Pittsburgh Press, 1955 (translated 1973).

Glacken, Clarence J., *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century*, Berkeley: University of California Press, 1967.

Gordon, Cyrus H., *Before Columbus; Links Between the Old World and Ancient America*, New York, Crown, 1971

Granzotto, Gianni, *Christopher Columbus: The Dream and the Obsession*, New York: Doubleday & Company, 1985.

Grosso, Orlando, *Il Palazzo San Giorgio,* Genoa, Italy: Sagep Editrice, 1987.

Hale, John R., *Renaissance Europe, Individual and Society, 1480–1520,* Berkeley: University of California Press, 1971, California Edition, 1977.

Heers, Jacques, *Christophe Colomb,* Paris: Haschette, 1981.

Higueras, Guadalupe C., *Naves del Descubrimiento la "Santa Maria" la "Pinta" y la "Niña,"* Spain: Zahara Ediciones, 1985.

Highfield, Roger, ed., *Spain in the Fifteenth Century 1369–1516, Essays and Extracts by Historians of Spain*, trans. by Frances M. Lopez-Morillas, New York: Macmillan, 1972.

Hobhouse, Henry, *Seeds of Change*, New York: Harper & Row, 1986.

Honour, Hugh, *The New Golden Land: European Images of America from the Discoveries to the Present Time,* New York: Pantheon Books, 1975.

Irving, Washington, *The Life and Voyages of Christopher Columbus,* New York: John B. Alden, Publisher, 1884.

Jane, Cecil, ed., *The Four Voyages of Columbus*, New York: Dover Publications, 1988.

Judge, Joseph and Stanfield, James L., "The Island of Landfall," *National Geographic*, November, 1986.

Landstrom, Bjorn, *Columbus: The Story of Don Cristobal Colon Admiral of the Ocean and his Four Voyages Westward to the Indies According to Contemporary Sources*, New York: Macmillian Co., 1966.

Lynch, John, *Spain Under the Habsburgs, Volume Two: Spain and America 1598–1700*, Second Edition, New York: New York University Press, 1969, 1981, 1984.

Lyon, Eugene, "15th Century Manuscript Yields First Look at Niña," *National Geographic*, November, 1986.

Marcos, Jose L. E., and Ramon H. Martin, *Colon En Salamanca Los Dominicos*, Salamanca: Europa Artes Graficas, 1988.

Marden, Luis, "Tracking Columbus Across the Atlantic," *National Geographic*, November, 1986.

Martz, Linda, *Poverty and Welfare in Habsburg Spain: The Example of Toledo*, Cambridge: Cambridge University Press, 1983.

Marx, Robert F., *Following Columbus, The Voyage of the Niña II*, Cleveland & New York, The World Publishing Company, 1964

Milanich, Jerald T., and Susan Milbrath, ed., *First Encounters: Spanish Explorations in the Caribbean and the United States, 1492–1570*, Gainesville: University of Florida Press, 1989.

Morison, Samuel Eliot, *Admiral of the Ocean Sea: A Life of Christopher Columbus*, Volumes 1 and 2, New York: Time, Inc., 1942, 1962.

Morison, Samuel Eliot, *Christopher Columbus, Mariner*, New York: Meridian, 1942, 1955, 1983.

Morison, Samuel Eliot, *The Great Explorers: The European Discovery of America*, New York: Oxford University Press, 1978.

Morison, Samuel Eliot, trans. and ed., *Journals and Other Documents Relating to the Life and Voyages of Christopher Columbus*, New York: The Heritage Press, 1963.

Morison, Samuel Eliot, *The European Discovery of America: The Southern Voyages, 1492–1616*, Oxford University Press: New York, 1974.

Nunn, George E., "The Geographical Conceptions of Columbus," *American Geographical Society*, Research Series No. 14, 1924.

Palau, Mercedes, *La Spedizione Malspina in America e Oceania 1789–1794*, Genoa, Italy: Sagep Editrice, 1987.

Parry, John H., *The Age of Reconnaissance: Discovery, Exploration and Settlement 1450 to 1650*, Berkeley: University of California Press, 1963 in London, England; California Edition, 1981.

Perry, Mary Elizabeth, *Crime and Society in Early Modern Seville*, Hanover: University Press of New England, 1980.

Penrose, Boris, *Travel and Discovery in the Renaissance, 1420–1620*. Harvard University Press, 1952, New York: Antheum, 1962.

Peterson, Mendel, "Reach for the New World," *National Geographic*, December, 1977.

Pike, Ruth, *Aristocrats and Traders: Sevillian Society in the Sixteenth Century*, Ithaca, New York: Cornell University Press, 1972.

Pike, Ruth, *Enterprise and Adventure: The Genoese in Seville and the Opening of the New World*, Ithaca, New York: Cornell University Press, 1966.

Pohl, Frederick J., *Amerigo Vespucci, Pilot Major*, Columbia University Press: New York, 1944, 1945.

Pohl, Frederick Julius, *The Viking Setttlements of North America*, New York, C. N. Potter, 1972.

Poleggi, Ennio, *Genoa, Portrait of a City*, Genoa, Italy: Sagep Editrice, 1985.

Romano, Ruggiero, *Alle Origini Del Mondo Moderno*, Italy: Luglio, 1967.

Rum, Piera, ed., *Nautical Charts From Ligurian Museums and Libraries From the 14th Century–17th Century*, Genoa, Italy: Analisi, 1988.

Rum, Piera, *Guida ai Musei della Liguria*, Milano, Italy: Electa Spa, 1987.

Sale, Kirkpatrick, *Conquest of Paradise*, Penguin Books, New York, 1990.

Schiaffino, Pro, *The Sailing Ships of Camogli*, Genoa, Italy: Sagep Editrice, 1987.

Small, Deborah, and Maggie Jaffe, *1492: What Is It Like to Be Discovered?*, Monthly Review Press, New York, 1991.

Snell, T. Loftin, *The Wild Shores: America's Beginnings*, Washington, D.C., National Geographic Society, 1974.

Snyder, John P., and Philip M. Voxland, *An Album of Map Projections*, U.S. Geological Survey Professional Paper 1453, U.S. Govern-ment Printing Office, 1989.

Van Sertima, Ivan, *They Came Before Columbus*, New York: Random House, 1976.

Waters, David W., *The Art of Navigation in England in Elizabethan and Early Stuart Times, Part One: The Development of the Art of Navigation in Europe in the Fifteenth and Early Sixteenth Centuries*, Greenwich: National Maritime Museum, 1978.

Wilford, John Noble, *The Mapmakers: The Story of the Great Pioneers in Cartography from Antiquity to the Space Age*, New York: Vintage Books, 1981.

Wilford, John Noble, "Discovering Columbus," *New York Times Magazine*, August 11, 1991.

Who "Discovered" America?

Classroom Activities

What Shape Is the Earth?

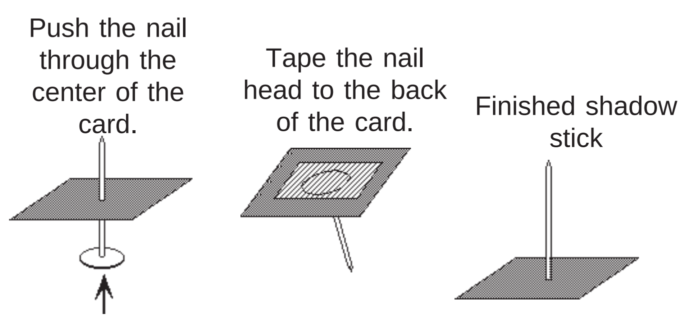
For nearly 2000 years before Columbus, people knew that the Earth was shaped like a ball. No one knows who first proposed this idea, but Pythagoras of Samos may have suggested it about 500 B.C. The idea was strongly supported by Aristotle. In about 350 B.C. Aristotle mentioned the disappearance of ships over the horizon, the Earth’s round shadow on the moon during an eclipse, and the changing positions of stars as a person travels southward. Unlike modern scientists, however, Aristotle believed that the Earth must be a sphere, because a sphere is a perfect shape!

In this activity, your students will explore one very important line of evidence, known in Ancient Greece, that supported the idea that the Earth is shaped like a ball. They will see that shadows of vertical sticks, placed at different locations around the Earth, have different lengths at the same time. This particular argument for the ball-shaped Earth premise lays the foundation for the next activity in which the students measure the Earth’s circumference.

Before the Lesson

Materials

- ❏ 1 large globe of the Earth without the cradle (at least 12" in diameter)
- ❏ 1 large flat map of the world
- ❏ 12 nails with large, flat heads about 1–2" long
- ❏ 12 pieces of stiff stiff paper, 1" x 1" cut from index cards
- ❏ 1 pair of scissors
- ❏ 1 roll of masking tape
- ❏ 1 ruler
- ❏ A sunny day



Preparation

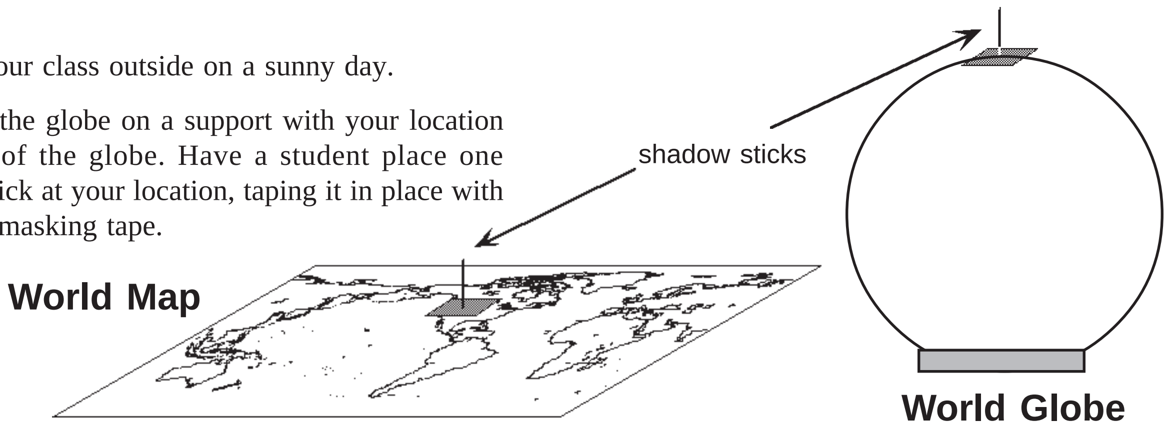
1. Make 12 shadow sticks by pushing the nails through the centers of the 1" x 1" pieces of stiff paper and taping the nail heads to the backs of the cards. For extra safety, blunt the ends of the nails with a file.

2. Make a few masking tape loops, with the sticky side out, so that the shadow sticks can be attached to the globe and flat map.

Part A. Shadows Around the Earth

1. Take your class outside on a sunny day.

2. Set up the globe on a support with your location on "top" of the globe. Have a student place one shadow stick at your location, taping it in place with a loop of masking tape.



3. Place the flat map of the world on the ground nearby. Have another student place a shadow stick at your location on the flat map and hold it in place with tape.

4. ***Ask a third student to use the ruler to measure and compare the lengths of the two shadows***.

5. Form a team of students to place five or six shadow sticks on the globe with tape in various sunny locations all over the world. ***Ask them to measure and compare the shadows. Are they the same, or different, and why?*** *(The shadows are different lengths because the globe is round.)*

6. Form another team of students to place five to six shadow sticks on the flat map of the Earth at the same locations as on the globe. ***Ask them to measure and compare the shadows. Are they the same, or different, and why?*** *(Approximately the same because this map of the world is flat.)*

7. Ask the students if their observations of shadows on the globe and flat map suggest a way to determine if the Earth is really flat, or round like a ball. *(We could have people in cities all around the world measure the lengths of shadows from vertical sticks of the same size. Then they call each other on the telephone. If the shadows are the same, the Earth is flat. If the shadows are different, the Earth is round!)*

Part B.
Finding the "No Shadow" Place

1. Have students experiment with the shadow sticks to find a place on the sunny side of the globe where there is no shadow cast by the nail. When the place is located, tape the shadow stick to the globe. It marks the place where the Sun is directly overhead at that moment in time.

2. Find the same place on the flat map, and compare the shadow on the flat map with the lack of shadow on the globe.

3. Try to find the "no shadow" place on the flat map of the Earth. The shadows on the flat map of the Earth will all be the same. The students will not be able to find a "no shadow" place on the flat map of the Earth.

4. Explain to your students that the varying lengths of shadows on the globe demonstrate what is observed on the real Earth. It is evidence that the Earth is round. Today we define the tropics as the portion of the world where there is at least one "no shadow" day each year when the Sun passes directly overhead at local noon. The next activity, How Big Is the Earth?, allows students to apply these concepts to measure the size of the Earth.

How Big Is the Earth?

In about 300 B.C. Eratosthenes, a librarian in Alexandria, Egypt, discovered how to measure the circumference of the Earth. This is one of the most astonishing achievements of ancient science. Only about 50 years after Aristotle described the evidence that supported the idea that the Earth is shaped like a sphere, Eratosthenes figured out how to measure its circumference. In this activity, your students will discover Eratosthenes' reasoning. Based on the evidence that Eratosthenes had available, they will calculate the Earth's circumference.

We suggest that you take into account the level of math understanding of your students. While making the calculation is easy, understanding the reasoning requires geometry skills. High school geometry students should have little difficulty. If you plan to introduce the activity with younger students, it is advisable first to introduce the two major mathematical concepts on which the activity depends: (1) You can measure the angle of a shadow formed by a stick as a fraction of a circle; and (2) Parallel lines cut by a straight line create equal angles.

Materials/Preparation

❑ Copy activity sheets for each student, using masters on pages 39 and 40: *How Big Is the Earth?—Part 1* and *How Big Is the Earth?—Part 2*

❑ Optional: 1 calculator per student

In Class — Eratosthenes' Method of Measuring the Earth

1. Ask your students to recall the previous activity, in which they learned one reason why people believed over 2,000 years ago that the Earth is shaped like a ball. Ask if anyone can suggest how to measure the size of the ball-shaped Earth. (Accept all answers.) Explain that in ancient times it was not possible to travel all the way around the Earth or into space. Nonetheless, a very intelligent librarian was able to figure out how large the Earth was.

2. Divide the class into teams of two or three students. Hand out the two activity sheets one at a time, allowing time for the students to read and discuss them in teams. Then lead a class discussion, answering questions as necessary. When discussing the distance between Alexandria and Syene, you may want to note that there is some dispute about the length of the unit of measurement (stadia) that Eratosthenes used in 300 B.C. According to J.L.E. Dryer, *A History of Astronomy from Thales to Kepler*, the most likely value of the Earth's circumference calculated by Eratosthenes was 24,662 miles. The modern value for the Earth's circumference is about 24,900 miles.

3. In conclusion, ask your class to imagine taking a 24,900 mile trip in a straight line on the surface of the Earth. They would travel in a great big circle all the way around the Earth and return to the same place! Eratosthenes knew this almost 2,300 years ago. Christopher Columbus did not have to prove that the Earth was shaped like a ball.

How Big Is the Earth? — Part 1

"My name is Eratosthenes. I'm a Greek scientist and librarian in the great library in Alexandria, Egypt. I have figured out a way to measure the distance around the ball-shaped Earth. Let me show you how you can do it too."

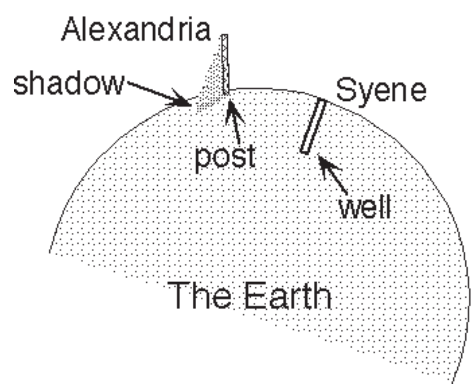
"I have read that at noon on the longest day of the year, the Sun's light shines directly down a well in Syene, a city that is several hundred miles to the south. (Locate Syene on the cross-section of the Earth on this page.) When I look at a vertical post in Alexandria at noon on the longest day of the year, the Sun's rays cast a shadow 1/8 the length of the post."

1. In the picture, draw the Sun, and show where it must be in order to shine directly down the well at noon in Syene ***and*** create a shadow in Alexandria.

2. If you see a vertical post in Syene at the same moment as the Sun shines directly down the well, does the post cast a shadow?

______yes ______no

3. Why do we see a shadow cast by the post at noon in Alexandria at the same time we see no shadow in Syene? What does this tell me about the shape of the Earth?



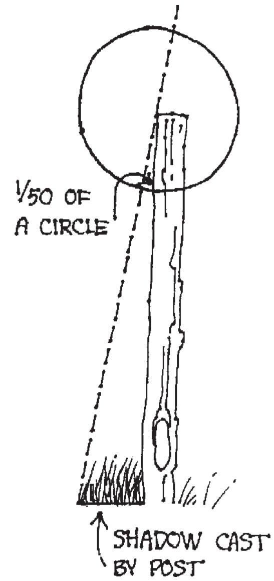
____

____

____

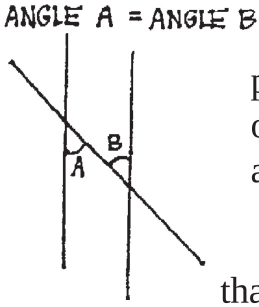
____

How Big Is the Earth? — Part 2

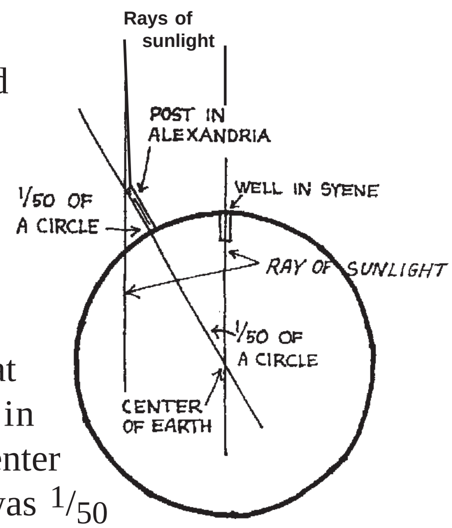


Eratosthenes continues his story.

"One of my favorite books is about geometry, written by Euclid. It helped me find out how big the Earth is. At noon on the longest day of the year in Alexandria, the length of a shadow cast by a post was about 1/8 the length of the post. From Euclid's geometry, I found that the angle at the top of the post must have been about $^1/_{50}$ of a circle."



"From Euclid I also learned that if I draw two parallel lines with one straight line crossing both of them, certain angles are equal. In the drawing at left, angle A = angle B."



"One day I read a book which said that at noon on the longest day of the year, the sun shines straight down a well in Syene, several hundred miles south of Alexandria. Since the Sun is very far away, a ray of sunlight that reaches Alexandria is parallel to a ray of sunlight that reaches Syene."

"When I drew a diagram of the Earth I realized that the angle of the shadow cast by the vertical post in Alexandria equals an imaginary angle formed by the center of the Earth, Alexandria and Syene. Since that angle was $^1/_{50}$ of a circle, the distance between Alexandria and Syene must be $^1/_{50}$ of the distance around the Earth."

"Then I paid someone to measure the distance from Syene to Alexandria by walking from one city to the other, and counting his steps. He measured the distance to be 5,000 stadia [about 493 miles in modern terms]."

How Big Is the Earth? (give answers on the back of the paper)

1. If 493 miles (793 km) is $^1/_{50}$ of the way around the world, how many miles is it all the way around the world? (Show your calculations.)

2. What is the circumference of the world by modern measurements? (Look it up!) How close was Eratosthenes' calculated measurement to the modern measurement?

.

Key for ***How Big Is the Earth—Part 1***

1. The Sun is directly overhead—straight over the city of Syene and the well.

2. When the Sun is directly overhead (see #1), a vertical post will not cast a shadow because the Sun is also directly over the post.

3. Eratosthenes sees a shadow in Alexandria because the Sun is not directly overhead in Alexandria. Alexandria is 493 miles (793 km), or about 7 degrees of latitude north of Syene, and the Sun can be directly overhead at only one place on the Earth at a time. Further, on a particular date, the Sun is directly overhead at noon for only one latitude around the globe, so places north and south of each other can never have the same shadow lengths at the same moment in time.

The Earth is shaped like a ball, and Eratosthenes knew it because there was a shadow from a vertical post at noon in Alexandria on the same day when there were no shadows at noon in Syene, a city south of Alexandria. On a flat Earth, all of the shadows would be the same at the same time of the day (in this case at noon).

Key for ***How Big Is the Earth—Part 2***

How big is the Earth?

1. If 493 miles (or 793 km) is 1/50 of the way around the world, how many miles is it all the way around the world?

50 x 1/50 = 1 whole circumference of the Earth. So the problem is solved by taking 50 times the distance of 493 miles between Alexandria and Syene.

50 x 493 miles = 24,650 miles, or

50 x 793 km = 39,650 km

This is Eratosthenes' estimate of the circumference of the Earth.

2. What is the circumference of the world by modern measurements?

24,906 miles, or 40,074 km.

How close was Eratosthenes' calculated measurement to the modern measurement?

Modern circumference:	24,906 miles	40,074 km
Eratosthenes' circumference:	24,650 miles	39,650 km
The difference:	256 miles	424 km

For older students, you may wish to calculate the percentage of error, which may be found by dividing "the difference" by "the modern circumference":

256 miles ÷ 24,906 miles = .01 = 1% or
424 km ÷ 40,074 km = .01 = 1%

Who Was Right?

When Christopher Columbus proposed his plan to sail west across the great Ocean Sea, he believed there was only one ocean, and one great body of land. Columbus’s plan was turned down several times before he succeeded in convincing the Spanish monarchy to support his venture. If he found a westward route to the Indies, Columbus knew that he would gain great wealth and fame for himself and for his sponsors, King Ferdinand and Queen Isabella. Why did it take Columbus so many years to obtain the ships and resources he needed? Why was he turned down so many times by monarchs all over Europe? It all has to do with three questions about geography. How big is the Earth? How wide is the ocean? How long does it take to sail across the Ocean Sea to the Indies?

Before the Lesson

Make one copy of each activity for every student, using masters on pages 43–45:

Who Was Right?—Part 1

Who Was Right?—Part 2

Who Was Right?—Part 3

In Class
Who Was right, Eratosthenes or Columbus?

1. Columbus did not have to prove that the Earth is shaped like a ball, but he did argue with the Queen’s learned counselors. What was the argument about, and who was right?

2. Divide the class into teams of two or three students. Hand out the three activity sheets one at a time, allowing time for the students to read and discuss them in teams. Then lead a class discussion, answering questions as necessary.

3. As you will see when reading the student activity sheets, one argument was over the size of the Earth. The other is over how much of the Earth is covered by land. Columbus believed he could cross the Ocean Sea in one month. The counselors disagreed, arguing that it would take three months. Columbus’s ships carried enough water and food for about one month, which meant that he and his crew could not make a three-month ocean crossing without restocking the ships. Although the counselors were right, Columbus was lucky. He made a trip of about one month and accidently arrived on islands that he believed were off the coast of the Indies. Columbus never gave up his belief that the world was small. Even though he made four voyages of exploration to Caribbean islands and traveled along the coast of the Central American mainland, he always believed he had discovered a new route to the Indies.

Who Was Right?— Eratosthenes or Columbus? — Part 1

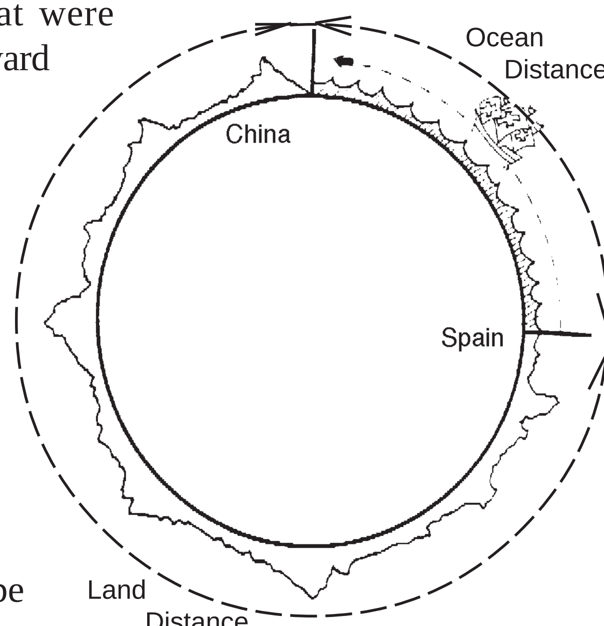
Queen Isabella and King Ferdinand of Spain appointed a committee to consider Columbus’s plan to reach the Indies by sailing west. The committee met in several places over the years. Columbus traveled to the meeting sites so he would be available to answer their questions.

Salamanca in December of 1486 was only one of these meeting places. It is probably the most famous because it was an important center of learning in Spain. The University of Salamanca was one of four great European universities of the time, together with the universities at Paris (France), Bologna (Italy), and Oxford (England).

Most educated people in fifteenth-century Europe believed that the Earth was shaped like a ball. The Queen’s counselors, who were professors in Salamanca, agreed with Columbus on this point. Their biggest concern was with Columbus’s claim that the distance from Spain to China, sailing west across the Ocean Sea, was so short. He had to convince them that the voyage was practical and within the possibilities of normal ships.

How did Columbus figure out the distance to China?

First, Columbus figured out the distances that were already known. People had already traveled eastward by land from from Europe to China and estimated the distance they had traveled. Second, Eratosthenes and others had measured the distance around the Earth.

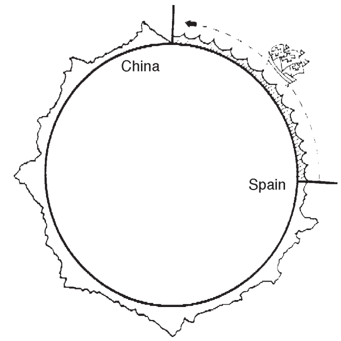


So, if Columbus subtracted the distance across the land from the distance around the Earth, he would know the distance from Spain to China, westward over the ocean. Remember, Europeans did not know that the Americas would be in the way.

Everyone who argued about how long it would be across the Ocean Sea to China used the same formula. The ocean distance *equals* the Earth’s circumference *minus* the land distance.

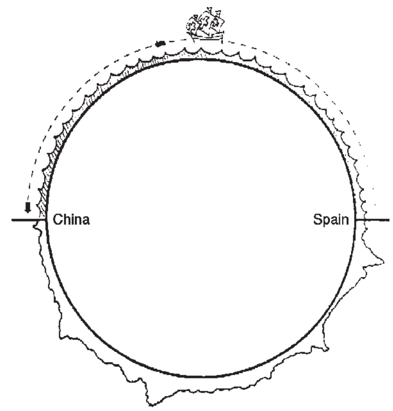
Who Was Right?— Eratosthenes or Columbus? — Part 2
Three Views of the Earth

Columbus claimed that the Earth is only 18,800 miles in circumference, and the land route from Spain to China is about 15,000 miles. How far did he think it would be to sail westward from Spain across the Ocean Sea to the Indies?



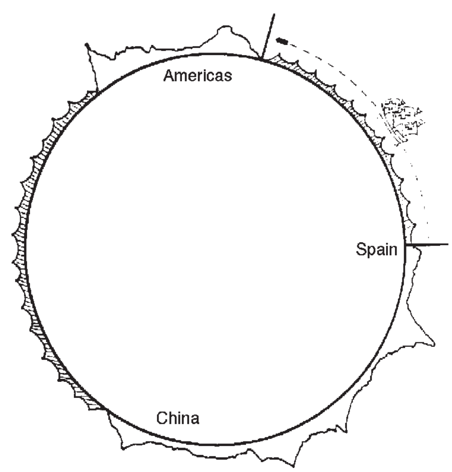
___________________miles

The professors at Salamanca disagreed. They thought the distance around the Earth was at least 20,000 miles as measured by Ptolemy (A.D. 150), and that the land route from Spain to China was no more than about 10,000 miles. How far did the professors at Salamanca think it would be to sail westward to the Indies?



___________________ miles

The modern view is that the distance around the Earth is about 24,900 miles, and the land route from Spain to the Indies is about 8,000 miles. How far would Columbus have had to sail to reach the Indies?



___________________miles

Why did Columbus *think* he reached the Indies, even though he made landfall in the Americas?

____

____

____

Who Was Right?— Eratosthenes or Columbus? — Part 3

Imagine that you are transported back in time to the university at Salamanca. You have an opportunity to listen to the historic argument between Columbus and the professors, appointed by King Ferdinand and Queen Isabella to give their expert opinions.

Columbus's presentation. Columbus says that it will take about one month to cross the great Ocean Sea and arrive in China. Ships of that time could carry enough fresh water and food for about a month, so there will be no problem in getting to China.

1. How big did Columbus believe the world to be? ______________________________

2. How much of the world did Columbus believe was covered with land?

____

3. If you were one of the professors, what would you like to ask Columbus?

____

____

The professors respond. The professors of Salamanca based their opinions about the world on astronomers like Eratosthenes and Ptolemy.

4. How big did the professors believe the world to be?___________________________

5. How much of the Earth did they think was covered by land? ___________________

6. What do you think the professors would have said to Columbus?______________

____

The modern view. Look at the modern view of the world.

7. Who was closer to the truth, Columbus or the professors?_____________________

8. If you were the King and Queen of Spain, would you have provided Columbus with three ships and a crew to try out his plan? _________________________________

Why or why not? ____

____

____

____

What's Your Latitude?

One of the most important tasks of a navigator is to determine where she is at all times. The height of the North Star above the horizon is affected by where you are on the Earth. The altitude angle of the North Star is a very good approximation (within 1° or better) for your latitude on Earth. In this activity, your students review how to find the Big Dipper and the North Star. Then they build a quadrant and practice using it to tell latitude.

Part A — Finding the North Star

Before the Lesson

Using an overhead projector to show stars creates a very nice "planetarium effect." Following are instructions to make a simple star frame for the constellations needed in this program.

Materials for a Star Projector

- ❏ 1 copy of star pattern, page 47
- ❏ 1 piece of aluminum foil large enough to cover the star pattern copy
- ❏ 1 piece of corrugated cardboard to protect surface of table or desk
- ❏ 1 pushpin and a sharp pencil
- ❏ 1 file folder or tag board to make a frame
- ❏ 1 roll of transparent tape
- ❏ 1 yellow paper star of your design to mark the position of the North Star on the wall
- ❏ 1 overhead projector

1. Make star holes in the aluminum foil.

a. Place the paper copy of the star pattern on top of the aluminum foil and the cardboard.

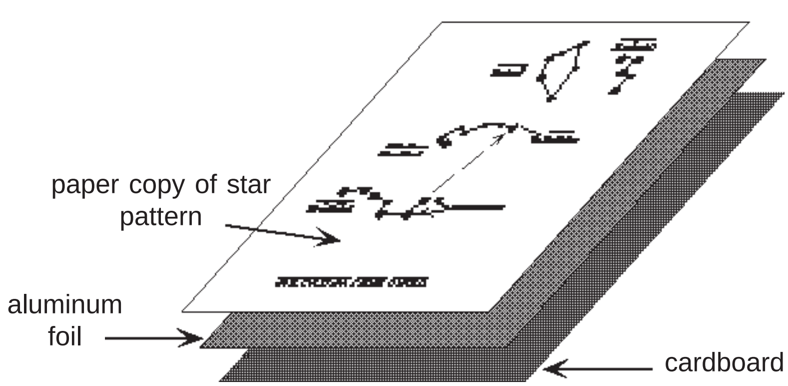
b. Use the pushpin to poke a hole through the paper and the aluminum foil for each star.

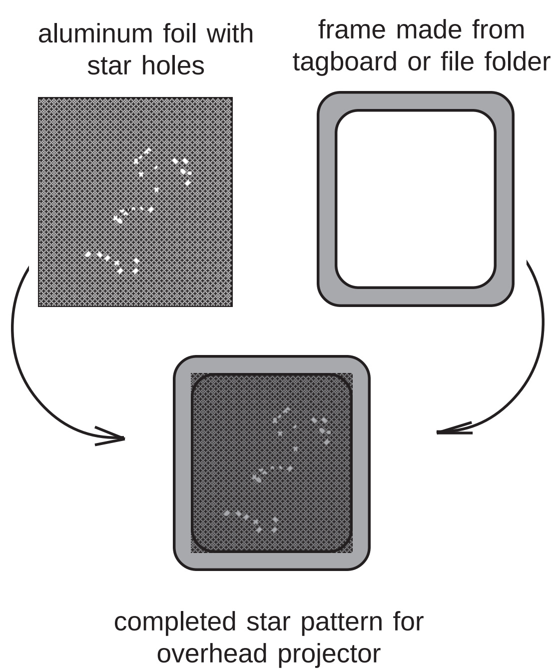
c. Remove the paper copy, and use the pencil to slightly enlarge the stars of the Big Dipper and the Polaris, the North Star. The larger the hole, the brighter the star appears.

d. Test the aluminum foil star pattern on your overhead projector.

2. Make a frame for the foil.

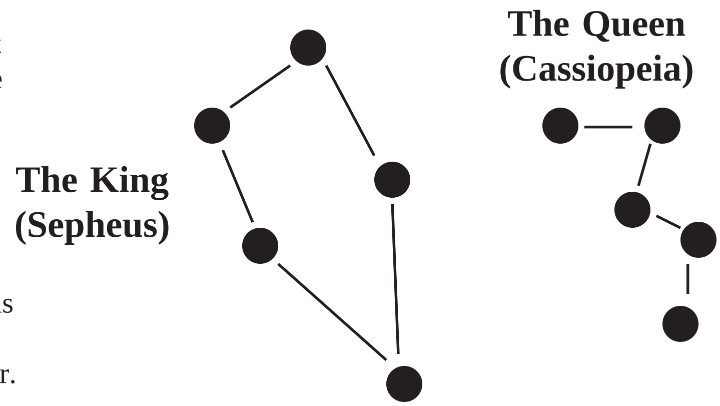
a. Make a frame for the aluminum foil from a file folder or tag board so that the entire surface of your overhead projector is covered by the framed star pattern.

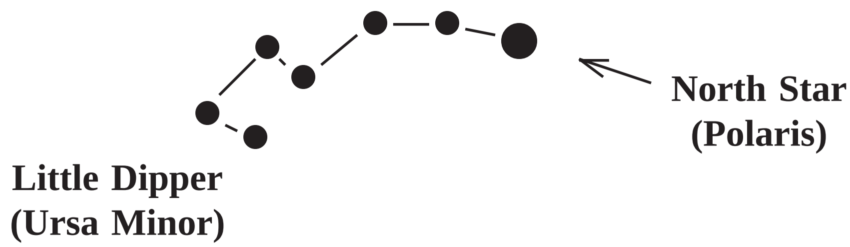


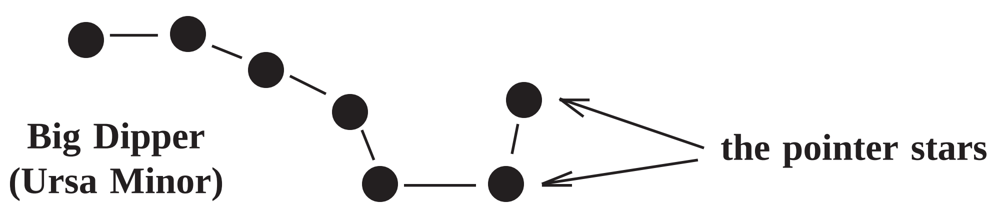


b. Mark the front side of the star pattern so that when you use it during the presentation, the star patterns are correct. If the frame is flipped over front-to-back, all of the star patterns will appear backwards.

Star Pattern for Projecting Stars in the Classroom: Use this pattern to make the framed aluminum foil star pattern, and use this diagram as a reference to teach your students the northern constellations that surround Polaris, the North Star.







In Class

Set up the overhead projector using the star pattern frame. Ask your students the following questions. Encourage the students to use the star projector in their explanations as well. You can supplement their answers as well. Sample answers are given after each question.

1. What is the North Star?

The North Star, Polaris, is used as a navigational star in *Who "Discovered" America?* and by real-life navigators for finding true north. All of the other stars appear to circle around the North Star once every 24 hours.

2. How can you find the North Star in the sky?

First find the Big Dipper (also called Ursa Major, the Big Bear.) The two front stars in the bowl of the Big Dipper point to the North Star. You can then find the much fainter Little Dipper (also called Ursa Minor, the little Bear), since the North Star is the end of the handle of the Little Dipper.

3. Why does the North Star seem to stay in one place?

As the Earth spins rotates. on its axis, the Sun, Moon, planets, and stars appear to rise and set, creating the cycle of day and night. The North Pole of the Earth points toward the same place in space throughout the year. We call the place in space where the Earth's North Pole points the *north celestial pole*. The North Star is within 1˚ of the *north celestial pole*, and we call it *Polaris* which means "pole star."

Part B. Make a Quadrant

A quadrant is a quarter of a circle. It is also the name of an instrument, shaped like a quarter of a circle, used by navigators in Columbus's day to determine latitude—how far north or south of the equator the navigator was located.

Materials for Making Quadrants

- ❏ 1 copy of "'Do-It-Yourself' Quadrant" for each student (master on page 6)
- ❏ push pins, one per student quadrant
- ❏ pencil eraser tip, small piece of cork or soft wood, one per student
- ❏ cardboard or file folder, 20 x 21.5 cm (8" x 8.5"), one per student
- ❏ glue stick, one for every two students
- ❏ scissors, one for every two students

In Class

Instructions for making and testing a Do-It-Yourself Quadrant

1. Have the students glue the quadrant sheet to the cardboard and cut it out.
2. Demonstrate how to assemble the quadrant according to the directions printed on the student copy of each quadrant. Have the students assemble their quadrants.
3. When assembled, check the pointer on each student's quadrant: it should swing freely.
4. To measure the altitude or height or an object, look along the top edge of the quadrant, aligning the back and front of that edge with the object. Wait until the pointer stops swinging.
5. Pinch the pointer against the scale; then read the angle from the quadrant.

To insure that students know how to use their quadrants correctly, take your students outside and measure the height of the school flag pole or a tall building from a distance. If the students stand close together, or in a line, their angular measurements should be very close to the same number. Any student who has a measurement more than 10° from the average probably needs some help in holding and sighting the quadrant correctly.

Emphasize that quadrants measure the altitude in ***degrees***. They do not measure directly the distance of something above the ground.

Demonstrate this by having your students measure the altitude angle of a distant object, like the top of a flag pole, and then go about half of the distance towards the object and measure it again. ***Is the altitude angle higher or lower?*** *(Higher.)* As they get closer and closer to the pole, the angle will get higher and higher, up to the limit of 90°. When they stand right next to the flag pole, and look up at the top, they will measure very nearly 90°. When they measure an object at eye level, such as the horizon, they will measure 0°.

Although the quadrant does not measure distance directly, you can calculate the distance above the ground if you know your distance from the object and use geometry or trigonometry.

Part C. Measuring the Altitude Angle of the North Star

1. Using the North Star overhead projector setup, challenge the students to measure the altitude angle of the North Star with their quadrants.

2. Switch off the overhead projector and tilt the projection lens so that the North Star will appear higher on the wall. Have students measure the altitude angle again. Ask, ***"Has the altitude angle increased or decreased?"*** *(Increased.)* ***"Would this mean that we are further north or further south on the Earth?"*** *(Further north.)*

3. Repeat step 2, but adjust the North Star lower than its first position.

4. How does my place on Earth affect where I see the North Star?

If you were to stand on the North Pole of the Earth, you would see the North Star at the zenith. As you walk south from the North Pole the only way to go!, you would see the North Star at a lower and lower altitude. By the time you trek to the equator, the North Star is on your horizon at an altitude of 0˚—the same as the latitude of the equator. Below the equator you would not see the North Star at all. Unfortunately, there is no South Star, since the Earth's south pole does not point to a visible star. South of the equator, navigators used other strs or the sun, and had to make more complicated calculations.

The North Star makes a very small circle around the north celestial pole. Serious navigators have to make adjustments for this, but the North Star seems to stay in one place for the ordinary stargazer.

Going Further

1. Geography Game

Using a large world map or globe, explain that latitude is the number of degrees north or south of the equator that a place is located. Its longitude is the number of degrees east or west it is of the prime meridian. The ***prime meridian*** is a north-south line that runs through Greenwich England.

a. Each team of 2 students picks a secret geographic location on a world map or globe that has latitude and longitude marked.

b. They write down on a piece of paper the word *Polaris*, their names, and the longitude of their secret place.

c. Each team labels a particular chair with a second piece of paper with their names on it

d. Using a quadrant, viewing from that chair, they find a particular spot on a wall which is the altitude angle that Polaris would be from their secret geographic place. This will require some trial and error to accomplish.

f. They tape their Polaris paper from step 2 to that spot on the wall.

g. Teams challenge each other to figure out their secret places by reading the longitude on the Polaris paper on the wall, and using a quadrant to determine the latitude by measuring the altitude angle of Polaris as viewed from the designated chair. It is important that chairs not be moved.

2. What's Your Latitude at Home?

When your students have learned to locate the North Star from the activities in *"Who "Discovered" America?* they can take their quadrants home, and measure the altitude of the North Star in the real night sky. Their measurement will vary ± 5°, but the class average will probably be close to the latitude of your school. You may obtain your latitude from a local airport, an atlas, your city planning office, or a United States Geological Survey map at the local library. The GEMS Teacher's Guide, *Height-O-Meters*, published by Lawrence Hall of Science, offers additional lessons focused on angular measurement for grades 6–10.

Background for Teachers:

Why Does the Height of the North Star Tell Us Our Latitude?

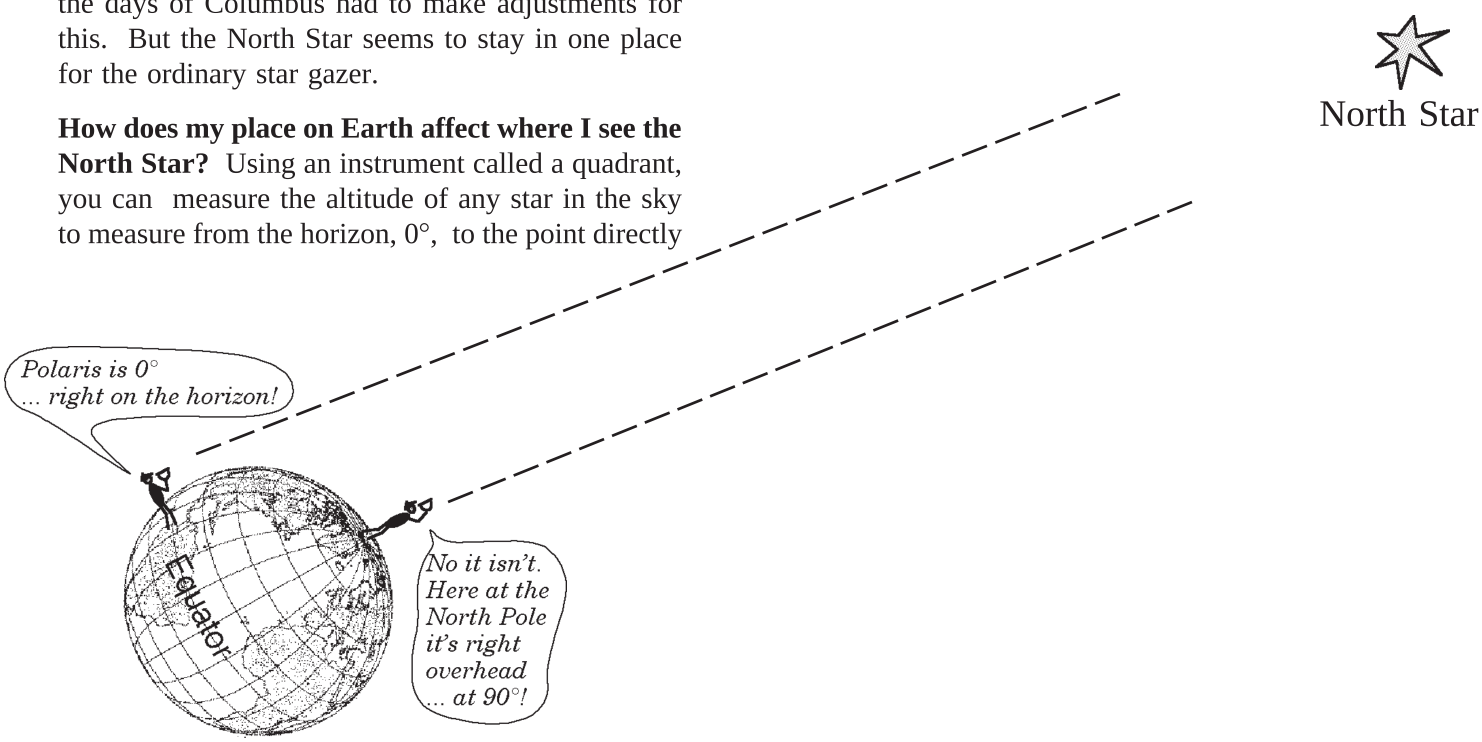
What is the North Star? The North Star, Polaris, is used as a navigational star in *Who “Discovered” America?* Real-life navigators use it for finding true north. All of the other stars appear to circle around the North Star once every 24 hours.

Where is the North Star in the sky? First find the Big Dipper. It is also called Ursa Major, the Big Bear. The two front stars in the bowl of the Big Dipper point to the North Star. You can then find the much fainter Little Dipper. It is also called Ursa Minor, the little Bear. The North Star is the end of the handle of the Little Dipper.

Why does the North Star seem to stay in one place? As the Earth spins (rotates) on its axis, the Sun, Moon, planets and stars appear to rise and set. This creates the cycle of day and night. The North Pole and South Pole of the Earth point toward the same place in space throughout the year. We call the place in space where the Earth’s North Pole points *the north celestial pole.* The Earth’s South Pole points toward the *south celestial pole.* The North Star is within 1° of the *north celestial pole.* We call that star *Polaris* which means “pole star.” The North Star makes a very small circle around the north celestial pole. Serious navigators in the days of Columbus had to make adjustments for this. But the North Star seems to stay in one place for the ordinary star gazer.

How does my place on Earth affect where I see the North Star? Using an instrument called a quadrant, you can measure the altitude of any star in the sky to measure from the horizon, 0°, to the point directly overhead, 90°. The point in the sky directly over each observer’s head is called the *zenith*. Your students can easily make one from a copy of the master on page 6. A star halfway between the horizon and the point directly overhead would have an altitude of 45°. If you were to stand on the North Pole of the Earth, you would see the North Star at your zenith. As you walk south from the North Pole (the only way to go!), you would see the North Star at a lower and lower altitude. By the time you trek to the equator, the North Star is on your horizon at an altitude of 0°. This is the same as the latitude of the equator. Below the equator you would not see the North Star at all. Unfortunately, there is no South Star, since the Earth’s South Pole does not point to a visible star.

How does the North Star help you to navigate? One of the most important tasks of navigators is to determine where they are at all times. As mentioned above, the height of the North Star above the horizon is affected by where you are on the Earth. In fact, the altitude of the North Star is a very good approximation for your latitude on Earth. If you measure the North Star’s altitude to be 90° then you must be at the North Pole. If you measure the North Star’s altitude to be 0°, you must be at the equator.



How accurately did Columbus read the North Star? Details about the accuracy of using the North Star to determine latitude are not discussed in this program. However, you may be interested to know that the Earth's axis does not point precisely at the North Star, but about 1° off. Over a very long period of time—about 25,800 years—the axis of the Earth slowly drifts in a giant circle, like the slow wobble of a spinning top. This motion is called *precession*. Because of precession, in the time of Columbus the North Star was $3^1/_2$° away from the north celestial pole, which is an important difference if you depend on it for your life. Like other navigators of his day, Columbus knew about this and used the positions of other stars in the Little Dipper to determine when the North Star was just to the left or right of the celestial pole (and not above it or below it), so that he could use his quadrant to determine his latitude accurately. When using the North Star to adjust the direction of his compass, Columbus made certain that it was just above or below the north celestial pole (and not to the left or right.)

How Does a Compass Work?

A compass needle is a tiny magnet that is suspended so that it can turn very easily. Since the Earth itself acts like a giant magnet, the needle lines up with the Earth's magnetic field. In the northern hemisphere, the needle points towards the Earth's **magnetic north pole**. In most places on Earth, compass needles do not point to true north. True north refers to the Earth's **geographic North Pole**, around which the entire Earth turns. The difference in direction between magnetic north and true north is called ***magnetic variation***. It is caused by the fact that the north magnetic pole of the Earth is not in the same place as the north geographic pole defined by the Earth's axis of rotation, and because iron in the Earth can cause local variations in the direction of the Earth's magnetic field. It is the Earth's north geographic pole that points toward the North Star.

As the ship's navigator on the Santa Maria, Columbus had to adjust the compass so that it would point true north. He did that by attaching a paper card to the needle. The needle pointed towards magnetic north. When he could see the North Star, he would adjust the card so it pointed towards the North Star or, more precisely, the north celestial pole. He then attached the card to the needle with something like tape, just as your students will do. The compass is then turned over to the helmsman, whose job it is to use the compass to steer the ship. The compass now indicates true directions so the ship's prow can be aligned with the direction they want to go. From Spain, Columbus directed the helmsman to sail southwest to the Canary Islands and then due west across the great Ocean Sea.

Your class may want to obtain the magnetic variation for your geographic area by checking a topographic or navigational map of your area. These are available from your local map shop, airport, or the United States Geological Survey.

You can also demonstrate a modern compass to show the deflection of the needle caused by a small magnet. Compass needles respond to the small magnet just as they do to the giant magnet, the Earth, where we live. You can use a regular compass and pass it around the room with a magnet for students to experiment.

Transparent modern magnetic compasses are available for classroom demonstration on the overhead projector. They are available from many sources (see page 3).

Hands-On Model of a Lunar Eclipse

Educational research shows that children (and many adults) have difficulty visualizing from diagrams and explanations alone, why an eclipse occurs. A very effective way to explain these concepts is through a hands-on model that allows the students to visualize the eclipse *from their own point of view*.

Materials

- ❏ 1 opaque white ball per student, 1" to 2" in diameter
- ❏ 1 lamp socket with plug—no shade
- ❏ 1 25-foot extension cord
- ❏ 2 clear (not frosted) light bulbs, one 40-watt, one 75-watt
- ❏ Optional: black paper, cloth, or garbage bags and tape to cover windows

Any opaque, white balls will work, including hardboiled eggs, golf balls, or white candy yogurt balls. Styrofoam does *not* work well, since it is translucent. Polystyrene balls are ideal to use for several classes because they are made of high-density foam and do not crush and crumble. Polystyrene balls may be purchased at some craft and fabric stores (especially in November and December), or ordered from:

Molecular Model Enterprises
116 Swift Street
P. O. Box 250
Edgerton, WI 53534
(608) 884-9877

Before the Lesson

- ❏ Darken the room completely—cover windows with black cloth, paper, or garbage bags if necessary
- ❏ Hang the lamp from the ceiling or clip it to a chair on top of a table, so the bulb will be in the center of the room, a little bit above eye level. Start with the 40-watt bulb.
- ❏ Experiment to see which of the bulbs is best before doing this activity with students. Push one of the moon balls onto a pencil to form a handle. Your students will be standing in a large circle to do this activity. Stand near the edge of the classroom, where your students will stand, and hold up the moon ball. Move the ball around your head,

In Class

What is a lunar eclipse? Imagine you are looking at a beautiful full Moon—a perfect bright circle of light against a starry night sky. All of a sudden you notice that there seems to be a shadow on one edge of the Moon! As you watch for the next half hour or so, the shadow gradually covers more and more of the Moon. A further mystery is that the shadow is not completely dark, but it glows a deep reddish orange. After an hour or two, the bright full Moon begins to appear again, and the shadow passes away as gradually as it came. You are again looking at the bright perfect disk of a full Moon. You have just witnessed an eclipse of the Moon, or **lunar eclipse**. Today we know that lunar eclipses occur when the Moon passes through the shadow of the Earth.

Let's use a model to find out what causes an eclipse of the Moon. Please stand up and take one of these "moons." Pretend your head is the Earth. Now I will turn on the "Sun" in the middle of the room.

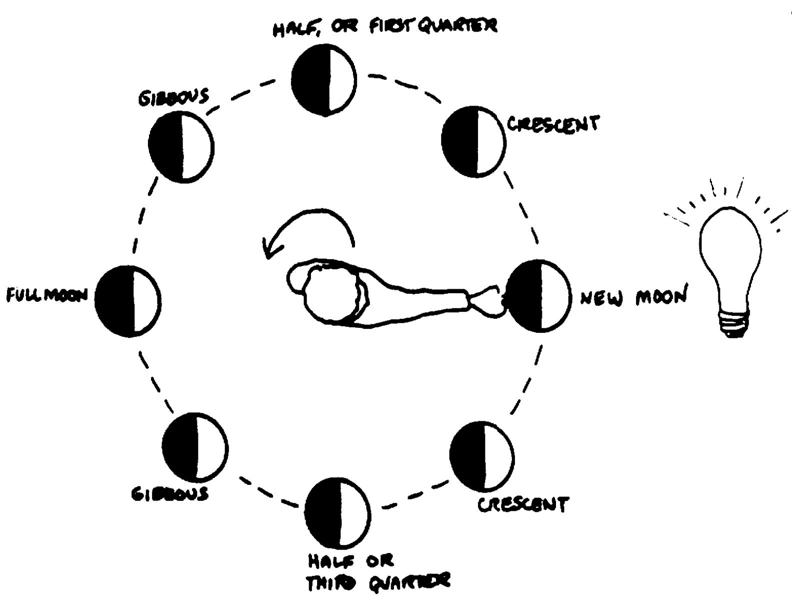
Distribute Moon balls, one to each person. Turn on the lamp at the center of the classroom, and turn off all other lights.

Hold your Moon up so it covers the Sun. That's a solar eclipse; it is not the type of eclipse Columbus saw. Now turn to your left so that you see a crescent Moon. It takes the Moon about one month (or one "Moon-th") to travel around the Earth. In that month, the shape or phase of the Moon changes slowly. (Check to be certain that the students are following you at each step. Help individuals as needed.)

Keep turning until your Moon is half full. Be sure to watch the Moon ball, not the Sun (the lamp) in the center of the room. Continue turning slowly until the Moon is almost full. *(Check on students.)* You have seen how the Moon changes its phase from crescent to full in almost two weeks.

Remember that your head is the Earth. Turn your back toward the Sun so that it is nighttime over your entire face. Now, slowly move the Moon into the shadow of your head. This is a lunar eclipse. Notice that you can still see the Moon a little bit from scattered light in this room. When the real Moon moves into the shadow of the Earth, it glows dull red because some of the red light of the Sun is bent by the Earth's atmosphere into the Earth's shadow.

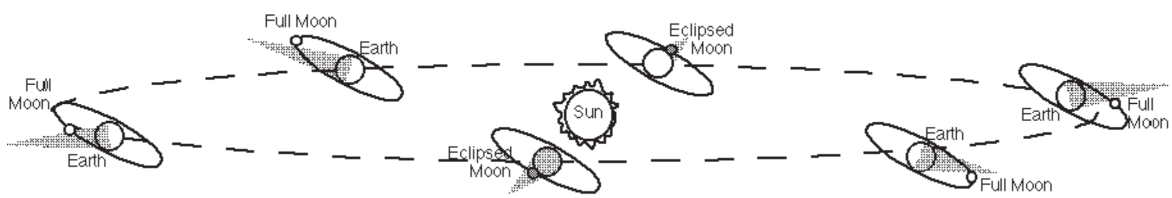
What phase is the Moon just before an eclipse of the Moon? *(Full.)* ***Just after an eclipse of the Moon?*** *(Full.)* The Moon must be at full phase in order for there to be a lunar eclipse. Most of the time, the full Moon passes just above or just below the shadow of the Earth, so we do not see an eclipse. But when the Moon does pass through the shadow, we can see a lunar eclipse. Now, place the Moon back into the shadow of your head. Remember, your head is the Earth. ***Where do you have to be to see the eclipse of the Moon?*** *(On the dark side of the Earth)* So, someone in Spain could watch the same eclipse that Columbus saw on the mystery island, as long as they could all see the Moon at the same time.



Background for Teachers — What Causes a Lunar Eclipse?

When do lunar eclipses occur? The Earth circles the Sun once per year. The plane of the Earth’s orbit is called the ***ecliptic***. The Sun, the Earth, and the Earth’s shadow all fall within the plane of the ecliptic. The Moon circles the Earth once per month. The plane of the Moon’s orbit is tilted a little bit (5°) from the plane of the ecliptic. When the Moon is on the side of the Earth away from the Sun, it passes very close to the Earth’s shadow; so there is a *chance* of an eclipse every month. Because its orbit is tilted, however, the Moon usually passes just above or below the Earth’s shadow. About twice per year the Moon goes right through the shadow of the Earth, creating a lunar eclipse.

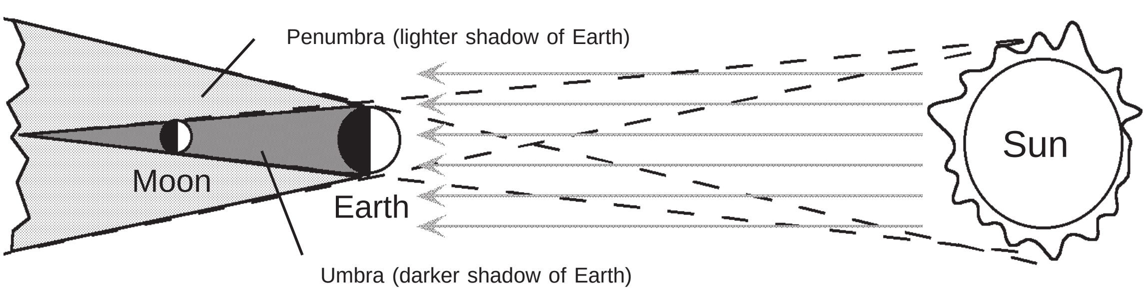
Columbus and the lunar eclipse. The script describes a lunar eclipse observed by Columbus at a mystery island (Jamaica). This was reported many years later by his son, Ferdinand, who was on the trip with him. During that eclipse the Moon did not pass through the center of the Earth’s shadow, so it was red-orange, and fairly bright. When the Moon rose, it was almost totally eclipsed. Columbus measured the time from sunset to the end of the lunar eclipse in order to determine his longitude. It was not a particularly accurate method because Columbus lacked good clocks, and determining the precise ending of a lunar eclipse is quite difficult. But it was the best method available.



Why lunar eclipses occur about two times per year: the Moon’s orbit is tilted with respect to the Earth’s orbit.

How frequently can you see a lunar eclipse? On average, a lunar eclipse occurs about once in six months. Notice that the night side of the Earth faces the Moon when it is in full phase. This means that *everyone* on the night side of the planet can see a lunar eclipse when it occurs. If there were no clouds your chance of seeing a lunar eclipse would actually be a little *more* than 50% because it takes the Moon a few hours to pass completely through the Earth’s shadow. So if the eclipse starts in late afternoon, you may still be able to see it come out of eclipse an hour or two after sunset.

Why does the Moon appear reddish orange during an eclipse? The Moon looks deep reddish orange because the Earth’s atmosphere bends the red-orange part of Sunlight into the shadow, just as it does at sunrise or sunset. The sky appears reddish when the Sun is below the horizon. How dark the Moon appears depends upon whether the Moon is crossing through the center of the Earth’s shadow or nearer to the edge of the shadow, and how much dust or pollution is in the Earth’s atmosphere.



Note: Distances and sizes in these diagrams are not to scale (by a long shot).

Students' Ideas About Columbus

On pages 57 and 58 is a student questionnaire we used to study what students already know about Columbus, and what misconceptions they may have. You can use this questionnaire as a pre- and post-test for the planetarium program *Who "Discovered" America?* and the classroom activities. We devised and administered the student questionnaire about what Columbus set out to do, what he accomplished, and the consequences of his voyages. Based on pilot studies, the questionnaire allowed for several kinds of responses, including multiple choice, essay, true-or-false, and drawings. We administered these questionnaires to 279 students in grades four through eight at four San Francisco Bay Area schools. Two of the schools were inner city schools with multi-ethnic school populations. The other two were suburban schools. Here are the results of our study.

Results of Our Pilot Study

Recall of basic information. We asked the students to name the three ships that Columbus used on his first voyage, so that they would feel a sense of accomplishment and be more willing to answer the essay questions that followed. We were quite surprised to find that, even ignoring spelling errors, only 32% of the students could name all three ships. Fifteen percent of students named the Mayflower as one of his ships!

Stories about Columbus state that he was born in Italy and sailed from Spain. This appears to be a source of confusion. When asked a true-or-false question about whether or not he was born in Seville, Spain, 55% of the students said it was true. When asked if he was born in Genoa, Italy, 53% of the students students said it was false. Given that the most likely distribution of responses to any true-or-false question is 50%, it appears that few students know the simple facts of Columbus's life. Our own research uncovered disagreements with the view that Columbus was born in Genoa, but such scholarly arguments have not found their way into the popular literature.

Size and shape of the world. Perhaps the most influential American biography of Columbus is Washington Irving's *Life and Voyages of Columbus* written in 1830. This volume gives the impression that Columbus was alone in maintaining that the world is round, and that sailors were afraid to sail with Columbus because they thought they would fall off the edge of the world. Many adults recall vivid illustrations of this idea in books they have read about Columbus. This idea is completely untrue. The idea that the world is shaped like a ball originated in ancient Greece. By 300 B.C., Eratosthenes, the librarian at Alexandria, Egypt, had devised a method of measuring the Earth's circumference. In Columbus's time the argument was about how far the journey was likely to be, not the shape of the Earth.

The results of our pilot study indicated that the old myths still prevail. When asked if it was true or false that "In Columbus's day, most educated people agreed that the world is round like a ball," 66% percent thought it was false. 73% percent thought that "Columbus was the first to believe that the world is round like a ball." When asked if people were afraid to go on Columbus's ships because "they thought they would fall off the edge of the world," 85% agreed. Only 49% agreed that the sailors "thought they would run out of food and water before they reached land."

What did Columbus prove? Columbus's aim was to find a more practical way of reaching Asia than by sailing around Africa. By doing so, he believed that he and his heirs would become wealthy. He was open to the possibility of finding new islands on the journey, but he never suspected that he might encounter unknown continents. He was never concerned with proving that the Earth was ball-shaped.

Our research showed that 82% of the students believed the myth that Columbus proved the world is round like a ball. Only among the fifth graders was there 45% that disagreed. When asked the open-ended question, "Why did Columbus want to sail to the Indies? List as many reasons as you can," 31% answered that he wanted to find spices and gold. 27% said he wanted to prove the world was round. 14% said he wanted to discover new lands.

Did Columbus discover America? Why or why not? This is a complicated question, and we were pleased to find that many students had interesting ideas about it. Overall, 36% of the students gave reasons why they believed Columbus discovered America, 42% gave reasons why he did not, and 22% did not justify their answers at all. The reasons they gave broke down as follows:

Yes, he did discover America.	**36%**
...because teachers or books say so.	10%
...various other reasons.	26%
No, he did not discover America	**42%**
...Indians discovered it first.	22%
...Vikings came first, or other reasons	20%
No justified answer	**22%**

The effect on Native Americans. How did Columbus’s arrival affect the people who already lived in America?” We were disappointed to find that students had a very limited perspective on the results of Columbus’s voyages. According to historical records within a few years of Columbus’s first voyage, millions died from fights with European forces and from disease. Columbus sent 500 Native people as slaves to Spain on his second voyage. However, only five percent of the students mentioned these dire consequences. Eight percent of the students noted that the Indians lost their lands. 13% said that the Indians were angry at, scared, or surprised by their encounters with the Europeans. 28% gave a wide variety of other answers. 46% did not answer the question at all. It is not surprising that students are unaware of the tremendously destructive effect that European contact had on the Native Americans. The elementary and middle school text and trade books we inspected tended to gloss over that aspect of the settlement of the Americas or did not mention it at all.

What does the study tell us?

The results of our preliminary study strike a familiar chord, which echos the headline news reports on the poor science and mathematics test scores of U.S. students in the past few years. We found that students had little understanding of what Columbus attempted to do, what he accomplished, and the consequences of his voyages to the American continents. Myths about Columbus are still widespread. However, there were two bright spots in our study. The first was a sample of 60 fifth graders, who seemed more knowledgeable about Columbus than the other classes. This suggests that specific instruction by a knowledgeable teacher may have made the difference. The second was that many students had interesting thoughts concerning whether or not Columbus should be credited with the discovery of America. Taken together, these findings suggest that:

1. Students in upper elementary and middle schools have a great deal to learn about Columbus’s experiment.

2. Students in this age range are thoughtful and capable of responding to new information that captures their attention and holds their interest.

If you use this student questionnaire, we’d like to know the results. Please send your responses to: Cary Sneider, Lawrence Hall of Science, Univeristy of California, Berkeley, CA 94720.

Student Questionnaire

Name____ Date______________

What Are Your Ideas About Columbus?

Please answer these questions in your own words.

1. What were the names of Columbus's ships?

____

2. People knew that the direction to the Indies by land was east. Columbus said that you could get there by sailing west. How did he explain this?

____

____

3. Columbus asked for ships and a crew, and he was turned down many times. Why was he turned down?

____

____

____

4. Why did Columbus want to sail to the Indies? List as many reasons as you can.

____

____

____

5. People say that Columbus discovered America. Do you agree? Why or why not?

____

____

6. How did Columbus's arrival affect the people who already lived in America?

____

____

____

____

Please circle the word *TRUE* or *FALSE* to show your opinion of each statement.

7. Columbus was born in Seville, Spain.	TRUE	FALSE
8. Columbus was born in Genoa, Italy.	TRUE	FALSE
9. Columbus was the first to believe that the world is round like a ball.	TRUE	FALSE
10. In Columbus's day, most educated people agreed that the world is round like a ball.	TRUE	FALSE
11. Columbus proved the world is round like a ball.	TRUE	FALSE
12. People were afraid to go on Columbus's ships because they thought they'd fall off the edge of the world.	TRUE	FALSE
13. People were afraid to go on Columbus's ships because they thought they would run out of food and water before reaching Asia.	TRUE	FALSE
14. Columbus made four voyages to the Americas.	TRUE	FALSE
15. Columbus died thinking that the Americas were really "The Indies" (China and Japan.)	TRUE	FALSE

Questionnaire Answer Key

1. Niña, Pinta, and Santa Maria were the names of Columbus's three ships.
2. Columbus knew that the world is shaped like a ball. So, if you sail west, you will eventually get to the Indies. If you keep going west by land and sea you'll end up where you started.
3. Columbus was turned down because other people believed the distance across the Ocean Sea from Spain to the Indies was much larger than Columbus thought it to be. They feared the ships would run out of food and water long before reaching the Indies.
4. He wanted to bring back gold, spices, silks, and other valuable items for trade throughout Europe. The advantage of a short water route to the Indies was to save on food, supplies, and the taxes at various ports and cities. If Columbus could bring goods to market more cheaply, he could undersell the competition. Also, if he encountered any Native peoples, he wanted to either convert them to Christianity or bring them back as slaves.
5. If students say "Yes," they may explain by saying that he "discovered" America from the viewpoint of Europeans who had not known about these continents before. If students say "No," then they may justify their answer by saying that Columbus did not know he had discovered a new continent; and/or that people already lived in the Americas when he arrived, and/or that other explorers from many continents had visited the Americas long before Columbus.
6. Millions of the people living in the Americas lost their lands, died by disease or suicide, or were killed outright by the Spaniards.
7. False. Columbus sailed from Seville, but was not born there.
8. True. There is considerable evidence that Columbus was born in Genoa, Italy.
9. False. It was widely believed that the Earth is round like a ball for over 1,800 years before Columbus.
10. True. In Columbus's day, most educated people knew that the Earth is a ball. This was especially true of sailors who had visited southern lands and seen the North Star disappear below the horizon when they crossed the equator.
11. False. Over 1,800 years before Columbus, ancient Greeks made various observations that supported the idea that the Earth is round. For example, as ships disappear over the horizon, we see their sails disappear last. The shape of the Earth's shadow on the moon is always round. Sailors who traveled far to the south observed different stars than they did in the northern skies. None of these lines of evidence "proved" that the Earth was round, but rather, led people to believe that the ball-shaped Earth idea was correct. Perhaps the most convincing evidence are photographs of the entire Earth taken by twentieth-century astronauts from space.
12. False. Sailors already knew that the Earth is shaped like a ball, and that there is no "edge" to the world.
13. True. Sailors were correct in believing that the Earth was bigger than Columbus thought and the distances greater. They feared they would run out of food and water before reaching the Indies. Luckily for them, the Americas were on their route between Spain and the Indies, so they were able to replenish their supplies.
14. True. Columbus explored the Americas during four voyages. He and his crews departed from Spain in 1492, 1493, 1498, and 1502.
15. True. All evidence is that Columbus died believing that the lands he explored were just off the coast of Japan, China, or India. His hopes of achieving great wealth and power were never realized. At one point he was imprisoned for mistreating Spanish settlers and sent back to Spain in chains.

Books About Columbus—An Annotated Bibliography

These books represent some of the available literature for children in grades K-12. In some cases, these books were consulted in the preparation of *Who "Discovered" America?* The bibliography was prepared by Marian Drabkin, Librarian of the Science Education Library at Lawrence Hall of Science, with contributions of other staff members.

Adler, David A. *Christopher Columbus: Great Explorer.* Holiday House, 1991 (A First Biography). Grades 3–6.

Well-written, easy to read, full of the vivid sensory detail that brings the time and place to life. This account shows Columbus as a strong and determined adventurer whose achievements were real though the consequences for natives of the Americas were tragic. A balanced portrayal of Columbus, amply illustrated on every page with pen-and-ink drawings that enhance and expand upon the descriptions of daily life on land and on board ship. A good choice for introducing biographical material.

Brenner, Barbara. *If You Were There in 1492.* Bradbury, 1991.

What was it like to live in 1492? What would you do, eat, wear? Daily life is discussed, focusing on Spain. Most books of this kind dwell upon the life of wealthy or at least prosperous people, such information being much more available as well as presumably more colorful. But Brenner chooses to give fascinating information concerning the lives of ordinary people; their food, clothing, hygiene or lack of it; their amusements; the science, medicine, and technology of the time. Everyday accepted cruelties are described, as well as examples of punishments for crimes or for religious or political nonconformity. Persecutions of the Jews and the Moors and the expulsion order of 1492 seem real and immediate. The readers are asked to imagine themselves as a Jewish child in Spain in that year, forced into losing a homeland, and perhaps losing life or family. Many well-chosen illustrations, explanatory notes, and a good index complete this interestingly written book whose sources are given in a bibliography of well-known adult-level, scholarly works.

Conrad, Pam. *Pedro's Journal: A Voyage With Christopher Columbus, August 3, 1492 –February 14, 1493.* Caroline House, 1991. Grades 3–6

The fictional story of the first voyage is told from the viewpoint of a young cabin boy who keeps a journal, complete with sketches. The difficulties, excitements, and hardships of the voyage are made vivid. Pedro describes the fears, pastimes, discontents of the crew, the bad food and the storms. He also describes the landing, and contact with the native peoples. The unthinking cruelty of the Spanish toward their native captives fills Pedro with shame. Native generosity toward the Spanish is "like a farmer opening the gate to let in a plague of grasshoppers." Well-written and thought-provoking, even reluctant readers will enjoy this realistic boy.

Finkelstein, Norman. *The Other 1492: Jewish Settlement in the New World*. Charles Scribner's Sons, 1989. Grade 6 and up.

When Columbus and his crew sailed out of Palos harbor their ships undoubtedly passed ships carrying Spanish Jews into exile, away from the land that had been their home for centuries. This gives insights into Spanish culture, as well as rounding out the picture of the time and place that produced Columbus and the Spanish conquest of the Americas.

Levinson, Nancy Smiler. ***Christopher Columbus: Voyager to the Unknown.*** Lodestar Books, 1990. Grades 4–7.

Vividly written, the details of Columbus's life and voyages, both frustrations and successes, make fascinating reading. The history behind the voyages is set forth, why it seemed so urgent to find new sea routes as well as the influences on this obsessive adventurer. The reader is shown a Columbus who is "an inventor of a new idea," a complex individual, "obsessed, faithful, weak, stubborn, patient, desirous of glory." The author also notes the effects on Europe of the agricultural and medical skills of the native peoples of the Americas. Illustrated with reproductions of paintings, archival prints and maps, and black and white photographs. The book includes a chronology, a list of crew members on the first voyage, a suggested reading list, and an index. It is a very complete as well as attractive and interesting biography

Meltzer, Milton. ***Columbus and the World Around Him.*** Watts, 1990. Grade 7 and up.

A very thoughtful, detailed, balanced discussion of the voyages, describing also the devastating consequences of European contact for the Native Americans, and the impact of that contact for Europe and the rest of the world. Columbus is shown here as a man very much of his own time and place, whose way out of troubles was to run away in search of the next dream. Many reproductions of paintings, archival maps, manuscripts, and drawings enhance this account. The author includes an impressive "Note on Sources" in which he explains how and why various sources were chosen.

Pelta, Kathy. ***Discovering Christopher Columbus: How History Is Invented.*** Lerner, 1991. Grades 5–8.

How is history written? How do historians decide some of the things we find in history books? How do they know what people thought and felt and did, even when there are no written records? Columbus, whose story has been pieced together and many times reinterpreted according to changing fashions of seeing the world, as well as new findings, is a perfect example of the process of creating history. In an interesting narrative, readers are given the currently known facts of Columbus's life, after which is given, chronologically, the history of Columbus' biography. It is not only who wrote what and when, itself a matter of interest, but what purposes were served at different periods. Thus the need for a non-English hero for the new United States gave rise to the "wise and brave, handsome and adventurous" idolized "discoverer." To Americans of the nineteenth century, Columbus became a symbol of the westward movement, facing down his mutinous crew with shouts of "Sail on!" And now, in the present concern for a more balanced view of history, historians are trying to present the viewpoint of the people who were here when Columbus arrived. Through all this chronology is the process of discovering history: the laborious piecing together of archival material; the tracing of documents; the comparison of various letters, logs, and diaries. The bibliography includes books on how to do research as well as an impressive number of books on Columbus for all ages. There are many well-chosen illustrations, and a good index. This is bound to give rise to many great class discussions. Not to be missed.