About the cover

As students progress through this guide, they will understand the features on the cover. In studying Unit I, Lesson 1, they will recognize Professor Quest. Unit II, Lesson 1, will enable them to identify the constellation depicting the Pythagorean Theorem. Lesson 6 in the same unit will provide students with the knowledge to identify Aristarchus’s model of the solar system. In Unit III, Lesson 2, they will learn about Hero’s simple machines and recognize the lever in one constellation. By studying Fibonacci’s numbers in Unit V, Lesson 2, students will understand the significance of the Nautilus constellation.

Parents, guardians, and teachers should supervise young readers who undertake the experiments and activities in this book. Always make sure that children follow instructions carefully. The authors and the publisher have made every reasonable effort to ensure that the experiments and activities in this book are safe when conducted as instructed but assume no responsibility for any accident, injury, loss, or damage arising from any of the experiments or activities in this book.
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Using the Teacher’s Quest Guide

STANDARDS

The lessons in this guide meet the National Science Education Standards, grades 5 – 8, and Benchmarks for Science Literacy, grades 6 – 8. Unit introductions list the specific standards and benchmarks met by the lessons in that unit.

LESSON FORMAT

• Sessions contain more activities than a class can accomplish during a typical class period. Select the most important activities according to students’ needs and abilities. For example, as students become grounded in an understanding of the time line and geography of events, de-emphasize these activities to emphasize science activities.

• The curriculum includes forty-five sessions.

• Five units each include an introduction (with background, materials list, and standards) and nine class sessions. Each unit includes one day to prepare for the assessment and one day for the assessment. A final assessment covers the entire book.

• Text-based lessons include reading, discussions, and activities to engage students in learning the material in The Story of Science: Aristotle Leads the Way.

• Science and math sessions include hands-on activities that give students an opportunity to act as scientific investigators. The activities duplicate historic experiments and allow students to observe natural phenomena both inside and outside the classroom.

Theme

Each lesson begins with a quotation from a scientist, great writer, or thinker that states the main idea of the lesson.

Goals

Each lesson has one or more specific goals for students to accomplish. These may include acquiring specific knowledge or building an understanding that will serve as a foundation for knowledge in future lessons.

Who? What? Where? When?

• Who? — scientists and other historic personalities
• What? — important terms
• Where? — geographic locations of events in the lesson
• When? — dates of historic events in the lesson

In some lessons, students find information and definitions during their reading to understand these terms. In other lessons, they draw on already defined terms to assist their reading.
**Groundwork**

A preparation checklist for the teacher appears at the beginning of the lesson. A list of materials for the teacher, the classroom, teams, and for students appears in the unit introduction.

**Consider the Quotation**

As a focusing activity, students decipher and paraphrase the theme quotation.

**Directed Reading**

Before assigning reading of a non-fiction passage, students set goals or ask questions so that they have a purpose for reading. What should they look for, note, and learn? To do this, they need prior knowledge on which to base questions.

In preparation for reading, students may do any of the following:

- Consider the title and/or theme quotation;
- Browse through the passage to look at illustrations, sidebars, charts, maps, and headings;
- Predict how a list of names and terms will apply to the passage;
- Speculate and ask questions about the main idea of the passage.

As students read the entire passage, they may pause to take notes on information they encounter that applies to their purpose for reading. When two students pair read, they share a reading assignment by reading portions to one another and stopping between passages to summarize, discuss, and question what they have read. Does the passage give any answers they are seeking? Does it raise new questions? What is interesting?

At the conclusion of the readings, students share and compare their findings in a class discussion.

**Cooperative Team Learning**

Students work in established cooperative teams (four students) to share and discuss ideas and concepts, debate issues, and develop and present projects. As teams work, each student must take equal responsibility to accomplish the task and support team members’ efforts. In some instances the team will produce a group project, but in most lessons each student will complete work individually based on the group activity. To help keep students on task and ensure that all team members participate and contribute, the teacher visits teams as they work.

**Classwide Activity**

The teacher interacts with the entire class to learn a concept or body of knowledge through discussion and demonstration.

**You Be the Scientist**

In these hands-on activities, students conduct experiments, solve scientific problems, and explore concepts studied.

**Scientists Speak**

As students study each scientist, they will have the opportunity to put words in that scientist’s mouth. What was the scientist’s most important discovery? What law or principle did he or she state
on which future scientists could base their work? The statement formulated by the class is written on a transparency showing a cartoon portrait of the artist. Photocopies of these transparencies serve as time line-additions.

**Conclusion**

Students revisit the lesson’s theme and their paraphrase of the opening quotation to summarize what they have learned and discuss the truth of the quotation. Students use their new knowledge and understanding to interpret the Professor Quest cartoon. The professor knows no boundaries in time, geography, or language. She communicates with the students, with the Greek-speaking philosophers, and with the medieval saints with equal ease. By asking important questions and commenting on significant events, she guides students on their quest through the story of science.

**Homework**

Students take home a brief independent assignment to reinforce the main points of each lesson, to prepare for a coming lesson, to further a project, or to collect material for a science session.

**Curriculum Links**

Activities in science, mathematics, geography, social studies, reading, language arts, music, and/or art appear at the end of each lesson. Select from these activities as time permits according to students’ interest and needs. Students will not have time to complete all of these activities. Some curriculum links may expand into additional lessons; some may provide ideas for presentations and projects.

**References**

Each lesson concludes with a list of web sites, books, and other sources used in compiling the lesson.

**CLASSROOM MATERIALS**

The following materials are needed for every lesson.

For each student: *The Story of Science: Aristotle Leads the Way* by Joy Hakim, *Student’s Quest Guide*, and a journal/notebook.

For the teacher: *The Story of Science: Aristotle Leads the Way* by Joy Hakim, and *Teacher’s Quest Guide*.

For the classroom: chart paper, an overhead projector, transparency markers, index cards, and a classroom time line.

**Time Line**

Before beginning the quest through *The Story of Science: Aristotle Leads the Way*, establish a time line using a long roll of shelf paper or a clothes line stretched around or across the classroom. The time line must be long enough to range from 700 B.C.E. to 2000 C.E., twenty-seven centuries.

Writing directly on the shelf paper or clipping index cards to the line, mark off the time line into twenty-seven even sections, each representing a century. Leave a bit of a tail after 2000 C.E. to mark the present, the beginning of the twenty-first century. Label the centuries beginning with 700 B.C.E.
at one end and ending with 2000 C.E. at the other. The centuries between 700 B.C.E. and 1500 C.E. will become very crowded, but allotting each century equal space on the time line will give students an accurate sense of distance in time between people’s lives and historic events.

As the lessons progress, students maintain the time line by adding people and events, using tacks, tape, or clip clothespins. Encourage students to replace the teacher-made time line markers with more creative ways to mark events. For example, students might replace the marker for Pythagoras with an illustration of his theorem. They might illustrate the Roman siege of Syracuse with a drawing of one of Archimedes’ war machines. New markers should still have labels recording the event and the date.

**Classroom Maps**

The class will need large maps of Europe, the Middle East, Northern Africa, and the world to supplement the maps in *The Story of Science: Aristotle Leads the Way*.

**Keys**

Duplicates of *Student’s Quest Guide* sheets provide the answers.

**Appendix**

The *Teacher’s Quest Guide* Appendix contains transparency masters to accompany each lesson. They include maps, quest sheets, Scientists Speak, Professor Quest cartoons, assessments, and other images specific to a lesson from which to make transparencies or copies.

**Student’s Quest Guide**

Each student will have a *Student’s Quest Guide*, which contains the following materials for each lesson.

- Theme
- Professor Quest cartoon
- Who? What? Where? When?
- Quest sheets

**Student Sheets**

For some science and math sessions, students receive student sheets, copied from masters in the *Teacher’s Quest Guide* Appendix. These are separate from the *Student’s Quest Guide* because they may go home as part of a homework assignment or may be disposable as part of a science activity.

**Journals**

Students maintain a journal during their study of *The Story of Science* in which they reflect on information they have learned; write creatively about people, events, and discoveries; and summarize important material using meaningful sentences.

Writing meaningful sentences using *Who? What? Where? When?* terms is a recurring assignment, which provides students with a tool to summarize main ideas. This tool will require modeling when first assigned and frequent reinforcement.

Explain to students that in a meaningful sentence, the writer embeds context clues that indicate a clear understanding of the new word. To test whether or not a sentence is meaningful, try replacing
the new word with another word. No other word, other than a close synonym, can replace the new word without changing the meaning of the sentence. In another test for a meaningful sentence, the writer encloses the new word in a box and underlines the words or phrases that serve as context clues.

For example, a meaningful sentence using the word “astronomy” might read, “Julia loves astronomy so much that she watches the heavens every clear night, studying the movements of the planets and the locations of the stars.” A not-so-meaningful sentence might read, “My teacher said we will study astronomy this term.”

Assessments

At the close of each unit, students will demonstrate what they have learned. Assessments may take a number of forms, including
• a creative cooperative team learning project,
• an open-book web and essay activity,
• an objective assessment.

Before teaching a unit, the teacher considers the possible assessment activities so that students have an opportunity to prepare as they progress through the lessons.

Ongoing Study

Students choose a topic for ongoing study through the curriculum. The teacher sets class time aside for periodic guidance and progress reports on the ongoing studies. Students may present the results of their ongoing study in a Science Story Fair with exhibits, reports, and presentations. Here are some possible areas of study.

• Follow art history (choose paintings, sculpture, architecture) from the periods and societies in which the scientists lived. Compare the styles, the attempts to represent reality, the subject matter, and the influence of scientific knowledge. Art links in at least one lesson per unit suggest an artist to research, and stable museum links offer many color images of artworks.

• Trace the progress of medical knowledge through the periods and societies in which the scientists lived. What ailments did the scientists have? How were they treated? What caused their deaths? What contributions to medical science did the scientists make? What public health problems occurred (the bubonic plague, malnutrition) and how did the societies deal with them?

• Collect an anthology of poetry or prose literature from the periods and societies in which the scientists lived. Compare the styles, moods, subject matter, and influence of scientific knowledge. Literature links in at least one lesson per unit suggest authors to research.

• Follow the history of timekeeping during the periods and in the societies in which the scientists lived. Build a model clock from one or more of the periods.

• Compile a Who’s Who? of people who played major roles in the periods and societies studied in fields other than science. Write brief biographies and find or create illustrations.

• Keep a sky journal. Find and mark a place on the sidewalk to stand each evening. Watch the sky and draw the night sky exactly as seen, paying careful attention to how high each sky object is in the field of view.
SAFETY IN THE CLASSROOM

Many of the activities in this guide involve exploration by students. In order for such activities to be conducted in an atmosphere of safety and security, teachers should be well prepared. Whether the activities occur in a classroom, in a laboratory, on the playground, or at home, appropriate equipment and facilities must be available, and adequate supervision must be provided. When safety becomes a state of mind, students not only become more secure but learn habits that extend to other areas of their lives.

There is no way to summarize all of the possible problems that might occur in an active classroom, or to list all of the precautions that should be taken to avoid potential hazards. However, general guidelines prove to be effective:

• Both teachers and students should be well prepared for each activity. Students must be present when precautions are discussed. Students should demonstrate their understanding of appropriate conduct before they begin.

• When students are active, both supervision ratios and space-per-student are important safety factors. Research shows that groups of over 24, and space per students lower than 45 square feet per student, both contribute to accident rates.

• In order to maintain order and maximize student interest, break exploratory activities into small steps with formative assessments and feedback after each section.

• Science materials must never be tasted or used for food after explorations.

• Encourage cleanliness with soap and hot water, both for hands and desks or tables.

• Eye protection is required for all chemicals, and whenever fire, heat, sharp objects, or projectiles might be present in the classroom.

• When chemicals are used, only very small (minimum) quantities should be present in the classroom. These quantities should be provided in labeled containers, with larger stocks of chemicals retained in separate, appropriately secure facilities.

• The only appropriate heat sources for students at the elementary or middle school level are low (tea) candles or (laboratory) hotplates.

A NOTE TO HOMESCHOOLING PARENTS

This curriculum is easily adapted to the homeschool setting. Each lesson is carefully outlined and explained, eliminating the need for exhaustive lesson planning. All materials needed for experiments and activities are readily available, and no expensive lab equipment is required.

Pair reading, which helps struggling readers in a traditional classroom, can be used to help a younger sibling keep up with challenging material. If only one student is using Aristotle Leads the Way, the home teacher can introduce the lesson and have the student read independently. At times, students work in pairs or teams to accomplish a task. In many instances, a younger sibling can be drawn into these activities, even if he or she is not studying Aristotle Leads the Way.

Homeschool teachers will appreciate the multidisciplinary elements in this curriculum, which include activities and topics in science, history, math, and language arts. Extension activities at the end of each lesson provide the home teacher with many ideas for further study and independent projects to add to the student’s portfolio.
# Aristotle Leads the Way

## INTRODUCTION – UNIT II

### Schedule

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<td>2</td>
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<td>Aristarchus's belief that the Earth orbits a stationary Sun; Moon activity</td>
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UNIT II — INTRODUCTION

Materials

Lesson 1
For the teacher
transparency masters
The Pythagorean Theorem
Scientists Speak: Pythagoras
Professor Quest cartoon #8

For the classroom
photocopy of
Scientists Speak: Pythagoras

For each student
ruler

Lesson 2
For the teacher
transparency masters
Scientists Speak: Democritus
Professor Quest cartoon #9

For the classroom
photocopy of
Scientists Speak: Democritus

For each team
two clear plastic cups
hot and cold water
a few drops of food coloring

Lesson 3
For the teacher
transparency masters
Scientists Speak: Aristotle
Scientists Speak: Plato
Professor Quest cartoon #10

For the classroom
photocopies of
Scientists Speak: Aristotle
Scientists Speak: Plato

Lesson 4
For the teacher
transparencies
Scientists Speak: Aristotle
Professor Quest cartoon #11

Lesson 5
For the teacher
transparency master
Professor Quest cartoon #12

Lesson 6
For the teacher
transparency masters
Scientists Speak: Aristarchus
Professor Quest cartoon #13

For the classroom
photocopy of
Scientists Speak: Aristarchus

Lesson 7
For the teacher
transparency master
Professor Quest cartoon #14
a daily newspaper showing sunrise/sunset times

Lesson 8
For each team
index cards (at least 24 per team)

Background

The ancient Greeks, using nothing but the human eye and reason, made astounding discoveries. It took centuries to improve upon—or, in the case of Aristotle’s cosmological misconceptions—disprove their theories. Believing that the universe was orderly and knowable, they set out to fathom its mysteries even without technological aid. A survey of ancient Greek cosmological beliefs is like a walk through a carnival midway museum: the preposterous (Pythagoras’s bent toward number-worshiping, bean-beatifying communes); the presumptuous (Aristotle’s Earth-centered cosmology and fifty-four rotating spheres); and the prescient
(Democritus’s theory of atoms and Aristarchus’s celestial calculations). They wedded math to science and provided the framework for future scientific discovery.

In the sixth century B.C.E., Pythagoras posited that the universe could be best understood through mathematics. Foreshadowing modern string theory, he extrapolated on his experiments with the mathematics of music to theorize that all the parts of the universe interact like instruments in an orchestra. Denying the popular stationary Earth concept, Pythagoras proposed that the Earth, Sun, and the planets all circle a large fireball. Celestial musings aside, Pythagoras is best remembered for the mathematical theorem that bears his name.

Two hundred years later, Democritus looked not to grand, cosmological macro mysteries but to the basic building blocks that undergird life. He theorized that atoms were the smallest substances in the universe and envisioned hard, solid, irreducible particles perpetually in motion. But lacking equipment to prove or disprove such theories, who could know for sure? His fellow philosophers turned instead to the study of reasoning. Plato searched for beauty, truth, perfection, and ideal forms. His pupil Aristotle, a great observer and synthesizer, attempted to create one theory to classify all knowledge. His mind ranged over the fields of biology, chemistry, astronomy, light, vision, and the study of logic, with remarkable results. His cosmological beliefs, however, steered astronomy off course for centuries. His Earth-centered universe featured special heavenly crystal spheres, perfectly circular orbits, and a celestial world composed of a unique element called “aether.” Aristotle rejected Democritus’s theory of atoms, arguing that everything on Earth was composed of four imperfect elements—air, earth, fire, and water. People still taught this into the nineteenth century—not a bad shelf life for a faulty proposition.

Aristarchus broke from tradition to hypothesize that the Earth revolved around a larger, stationary Sun. He also figured out that the Earth rotates on an inclined axis to cause day and night and seasons. Amazingly, he came within a fraction of correctly calculating the size of the Moon and the exact tilt of the Earth. Unfortunately, it took 1,700 years for his ideas to catch on; not until the fifteenth century did a monk named Copernicus resurrect and champion Aristarchus’s ideas.

Math Session

Unit II, lesson 1, includes a math activity in which students work with the Pythagorean Theorem.

Science Session

In lesson 5, “Why Mars Is A Little Loopy,” students demonstrate retrograde motion. In lesson 7, “Changing Seasons,” students demonstrate how the Earth’s rotation on an inclined axis affects the length of days and the amount of sunlight received, and how the Earth’s tilt causes seasons.

Assessment

Unit II offers three assessment activities.

- Cooperative Team Learning — Teams compose and perform a science story rap.
- Students use a web to organize and write an essay that compares or contrasts two cosmologies (open book).
- Students demonstrate mastery through a multiple choice and short answer assessment (closed book).

Standards

National Science Education Standards

Science as Inquiry

- Mathematics is important in all aspects of scientific inquiry.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.

Earth and Space Science

Earth in the Solar System

- The Earth is the third planet from the Sun in a system that includes the Moon, the Sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The Sun, an
average star, is the central and largest body in the solar system.

- Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the Moon, and eclipses.
- The Sun is the major source of energy for phenomena on the Earth’s surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the Sun’s energy hitting the surface, due to the tilt of the Earth’s rotation on its axis and the length of the day.

**Science and Technology**

- Many different people in different cultures have made and continue to make contributions to science and technology.

**History and Nature of Science**

**Science as a Human Endeavor**

- Women and men of various social and ethnic backgrounds—and with diverse interests, talents, qualities, and motivations—engage in the activities of science, engineering, and related fields such as the health professions. Some scientists work in teams, and some work alone, but all communicate extensively with others.

**History of Science**

- Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.
- In historical perspective, science has been practiced by different individuals in different cultures. In looking at the history of many peoples, one finds that scientists and engineers of high achievement are considered to be among the most valued contributors to their culture.
- Tracing the history of science can show how difficult it was for scientific innovators to break through the accepted ideas of their time to reach the conclusions that we currently take for granted.

**Benchmarks for Science Literacy**

**The Nature of Science**

**1A The Scientific World View**

- Scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.
- Some scientific knowledge is very old and yet is still applicable today.

**1C The Scientific Enterprise**

- Important contributions to the advancement of science, mathematics, and technology have been made by different kinds of people, in different cultures, at different times.

**The Physical Setting**

**4B The Earth**

- Like all planets and stars, the Earth is approximately spherical in shape. The rotation of the Earth on its axis every 24 hours produces the night-and-day cycle. To people on Earth, this turning of the planet makes it seem as though the Sun, Moon, planets, and stars are orbiting the Earth once a day.

**4D Structure of Matter**

- Scientific ideas about elements were borrowed from some Greek philosophers of 2,000 years earlier, who believed that everything was made from four basic substances: air, earth, fire, and water. It was the combinations of these “elements” in different proportions that gave other substances their observable properties. The Greeks were wrong about those four, but now over 100 different elements have been identified, some rare and some plentiful, out of which everything is made.

Because most elements tend to combine with others, few elements are found in their pure form.

**Historical Perspectives**

**10 F Understanding Fire**

- From the earliest times until now, people have believed that even though millions of different kinds of material seem to exist in the world, most things must be made up of combinations of just a few basic kinds of things. There has not always been agreement, however, on what those basic kinds of things are. One theory long ago was that the basic substances were earth, water, air, and fire. Scientist now know that these are not the basic substances. But the old theory seemed to explain many observations about the world.

**Habits of Mind**

**12B Computation and Estimation**

- Calculate the circumference and areas of rectangles, triangles, and circles, and the volumes of rectangular solids.

**12D Communication Skills**

- Organize information in simple tables and graphs and identify relationships they reveal.
- Locate information in reference books, back issues of newspapers and magazines, compact disks and computer databases.

**12E Critical Response Skills**

- Be aware that there may be more than one good way to interpret a given set of findings.
- Notice and criticize the reasoning in an argument in which fact and opinion are intermingled or the conclusions do not follow logically from the evidence given.
“Getting Atom”

Theme

“Colors, sweetness, bitterness, these exist by convention; in truth there are atoms and the void....”

Democritus (ca. 460 – ca. 370 B.C.E.)

Goal

Students will understand that ancient Greek philosophers developed a remarkably advanced atomic theory. Centuries would pass before scientists would further develop atomic theory.

Who?

Democritus — a fifth-century-B.C.E. Greek philosopher who believed that atoms were the smallest particles of matter

Epicurus — a fourth-century-B.C.E. Greek philosopher who believed in atoms and that they are constantly in motion

Socrates — a fifth-century-B.C.E. Greek philosopher who studied the human soul and told followers to “know thyself”; taught Plato

Aristotle — a fourth-century-B.C.E. Greek scientist/philosopher; did not believe in atoms

Leucippus — fifth-century-B.C.E. Greek philosopher who conceived idea of atoms as solid, indestructible, constantly moving particles

Where?

Thrace — country west of the Black Sea, birthplace of Democritus

When?

460 B.C.E. — birth of Democritus, who developed an early atomic theory

What?

atom — according to Democritus, the basic building block of life; small particles that make up everything in the universe and can’t be cut or destroyed

convention — agreement or custom

void — an empty space or nothingness; the opposite of matter

Groundwork

• Read chapter 10, “Getting Atom.”

• Gather the materials listed for lesson 2 in the unit introduction.

• Make time-line cards for the following dates.
1803 — John Dalton formulates a theory of atoms
1897 — J. J. Thomson discovers that atoms contain smaller particles called electrons

**Consider the Quotation**

1) Direct students’ attention to the theme quotation on page 31 in the *Student’s Quest Guide.*
2) Ask students to paraphrase this quotation from Democritus, assisting them with unfamiliar vocabulary, to be sure they understand its meaning.
3) Write student versions on chart paper or the chalkboard.
4) Tell students that in the chapter they will read today, “Getting Atom,” they will learn about an ancient Greek who developed a remarkably accurate theory of atoms nearly 2,500 years ago.
5) Display the transparency *Scientists Speak: Democritus* and tape the photocopy to the chalkboard. Ask students to prepare during their reading and discussions to put words in Democritus’s mouth.

**Directed Reading**

**Read to find out about Democritus’s theory of atoms**

1) Discuss with students the chapter title, “Getting Atom.” Ask students the following questions to stimulate interest.
   - What is an atom?
   - When did scientists first propose a theory of atoms?
   - What obstacles did scientists—especially ancient scientists—face in trying to prove a theory of atoms?
2) Students browse through chapter 10 to look at illustrations and sidebars. Ask students to pose any additional questions for their reading based on the theme quotation and their brief browsing.
3) Write students’ questions on chart paper or on the chalkboard.
4) Explain that Democritus was born around 460 B.C.E., approximately 100 years after Pythagoras. While Pythagoras believed that everything in the universe could be explained through mathematics, Democritus sought to understand the universe by developing a hypothesis of the smallest universal building block of life—something he called atoms.
5) Direct students’ attention to the map on page 87 to locate Thrace. Students pair read chapter 10 to discover Democritus’s ideas about atoms.
6) Students revisit the questions posed earlier in class. Class discussion should include most of the following points.

Democritus, an ancient Greek philosopher who lived in approximately 400 B.C.E., and his teacher Leucippus believed that everything in the universe is made of atoms. They believed these basic building blocks of life were the smallest substances in the universe, were hard and solid, were perpetually in motion, and couldn’t be cut up or destroyed. After Democritus, however, the hypothesis of atoms was not advanced because ancient Greek philosophers lacked the technology to prove or further explore this concept. They turned instead to the study of human emotions and thought. Socrates and his student Plato turned from physical science to a study of the human soul. Aristotle, Plato’s pupil, never believed in atoms.

8) Display the transparency *Scientists Speak: Democritus* on the overhead. What was his most important idea? What hypothesis did he state on which future scientists could
base their work? Students review chapter 10 to determine Democritus’s most important discovery. Write students’ suggestions on the chalkboard.

9) Write the statement in the speech balloon on the transparency. Ask a volunteer to copy it onto the photocopy and hang Democritus on the time line.

**Classwide Activity**

**Update the Timeline**

1) Remind students that although Democritus’s atomic hypothesis may seem simple to us today, it was a profound achievement.

2) Ask a student to locate Democritus’s birth on the class time line (approximately 460 B.C.E.). Tell students that further developments in the theory of atoms would not occur until the work of British chemist and physicist John Dalton in 1803. The knowledge that atoms were not indivisible (as Democritus had believed) was not discovered until 1897 with the work of J. J. Thomson. Ask a student to place time-line cards on these dates.

3) Ask students to calculate how many centuries passed before Democritus’s ideas were further developed (twenty-two centuries).

**Cooperative Team Learning**

**Recognize the difference between hypothesis, theory, and fact**

1) Ask students to speculate on the difference between hypothesis, theory, and fact and to define each. (These terms were first introduced in chapter 2.) It may be helpful to write the following definitions on chart paper or on the chalkboard.

**hypothesis** — a possible and reasonable explanation for a set of observations or facts

**theory** — a well-tested explanation of observations or facts; a verified hypothesis

**fact** — information that has been tested and shown to be accurate by competent observers of the same event or phenomenon

2) Tell students that new knowledge and understanding prove many hypotheses and theories wrong. For example, Pythagoras believed that the Earth, the Sun, and the planets all circle a great heavenly fireball. Of course, we now know that his hypothesis—which he formed after studying the heavens—is not true.

3) Students turn to page 32 in their *Student’s Quest Guides, Hypothesis, Theory, Or Fact?* Working with a partner, students complete the quest sheet.

4) Students share their work in a class discussion.

**You Be the Scientist**

1) Direct students to *Thinking About the Invisible* on page 34 in their *Student’s Quest Guides*. Explain that this activity will help students understand how molecules act even though we can’t see them.

2) Distribute materials listed in the unit introduction to each team. As students conduct the activity, circulate and monitor to answer any questions and ensure they are on task.

3) In a class discussion, explain that all molecules vibrate and bounce around to some degree. Heat provides energy to molecules, making them move more quickly. The physical principle of entropy causes the molecules to become less organized. On a visible level, we say that the food coloring dissipates (disperses) throughout the water molecules faster in warm water than in cold water.

**Conclusion**

1) Display the Professor Quest cartoon #9 on the overhead projector.
2) Ask students to relate the cartoon to the theme of the lesson.

**Homework**

Students write a letter to Democritus updating him on developments in atomic theory by Dalton and Thomson.

**Curriculum Links**

**History link** — Using library and Internet resources, students research the development of astronomy in ancient China during the fifth century B.C.E.

**Art link** — Using library and Internet resources, students research classical Greek architecture of this period, such as the Parthenon.

**History/Language Arts link** — Students use Internet and library resources to research the historical and political significance of the Oracle at Delphi. Students use this information to design a travel brochure promoting the Oracle.

**History link** — Confucius, the Chinese philosopher, was born in 480 B.C.E. Using library and Internet resources, students research the development and beliefs of Confucius.

**Science link** — Hippocrates, the Greek physician known as the “Father of Medicine,” was born in 460 B.C.E. Using library and Internet resources, students research the life and legacy of Hippocrates.

**Language Arts link** — Using library or Internet resources, students read excerpts from Lucretius’s *On the Nature of the Universe* and explore his belief in Epicureanism and his theory of atomic structure.

**References**


Hypothesis, Theory, or Fact?

hypothesis — a possible and reasonable explanation for a set of observations or facts

theory — a well-tested explanation of observations or facts; a verified hypothesis

fact — information that has been tested and shown to be accurate by competent observers of the same event or phenomenon

Read the following passages from chapter 10 to determine if they are hypothesis, theory, or fact. Write a brief defense.

1. “The Ionians had come up with those four basic elements: earth, air, fire, and water.”

   This hypothesis of the Ionians has been disproved. We now know that there are far more than four elements in the universe.

2. “He (Democritus) said there had to be a smallest substance in the universe that can’t be cut up or destroyed and is basic to everything else.”

   Democritus’ hypothesis of atoms is partly true. We now know that while atoms are basic to everything else, they can be cut, and are composed of still smaller particles.

3. “Atoms are unable to be cut.”

   While the Greek word for “atom” does in fact mean “unable to be cut,” we now know that this hypothesis was not correct. Atoms are composed of still smaller particles and can be split.
4. What pattern do you see in your answers? Why do you think this is so?

Democritus and the other ancient Greeks lacked modern technology, so they were unable to prove or disprove their hypotheses. The technology to prove the existence of atoms did not exist until the nineteenth century.

5. “Many subatomic particles, such as quarks, leptons, and neutrinos, have been found. Does that mean Democritus was wrong? Or is there something that unites all those subatomic particles? No one is sure, but many physicists are betting on Democritus and his hypothesis. They are searching for the smallest unifying particles within all matter. So far, there are clues but no proof.”

As author Joy Hakim points out, there are clues that this hypothesis may be true, but it has not been proven to be a fact.

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Scientists Speak

Democritus (ca. 460 – ca. 370 B.C.E.)
You Be the Scientist

Thinking about the Invisible
To explain what we see with our eyes, sometimes we have to imagine what we can’t see.

Your Quest: Atoms are the building blocks of matter; the smallest portion of a particular substance. Atoms combine in an infinite number of ways to form molecules. Can we learn how molecules act if we can’t see them?

Your Gear: You’ll need two small, plastic cups, some hot and cold water, and a few drops of food coloring.

Your Routine:
1. Place two flat cups on a firm surface. Fill one with hot water (not too hot!). Fill the other with the same amount of cold water.
2. Place two drops of food coloring in the cups. Don’t bump the table. Watch the glasses for two minutes. Draw what you observe.

Reporting Home: What happened?

How could the spread of the food coloring be explained by the motion of atoms? What can we conclude about motion in hot water versus cold water? Why?

Suggest a way that your whole class could model these molecules in a dance. (Suppose one group of students wore red T-shirts, representing the food coloring, and the rest of the class wore blue T-shirts, representing the water. Write directions for a warm water dance and a cool water dance for your classmates.)
Assessment I

Create a game to review the philosophers and concepts in Unit II

Groundwork

• Make copies of Unit II, Assessment I.
• Gather the materials listed for lesson 8 in the unit introduction.

Cooperative Team Learning

1) Distribute copies of Unit II, Assessment I and index cards to each team.
2) Read the directions and answer questions before the teams begin work on their games.
3) Visit the teams as they work to ask and answer questions and to make sure that all students are participating.

Alternate Assessment I

Compose and perform a science story rap

Groundwork

• Make copies of Unit II, Alternate Assessment I.
• Gather the following materials.

For each student

Unit II, Alternate Assessment I
Student’s Quest Guide
The Story of Science: Aristotle Leads the Way, chapters 9 – 13
paper and pen/pencil

Cooperative Team Learning

1) Distribute copies of Unit II, Alternate Assessment I to each team.
2) Review the model rap or a student-composed rap from Unit I. The teacher may choose to have students recite it.
3) Students work with teammates to compose a science story rap. Read the directions and answer questions before the teams begin work on their raps.
4) Visit the teams as they work to ask and answer questions and to make sure that all students are participating.
5) If the class does not use this assessment, students might enjoy reciting the sample rap as a closing activity for Unit II.
6) Students use the preparation for assessment day to compose their raps. Save enough time on the assessment day for teams to perform their raps.

Assessment II

Use a web to organize information and write an essay comparing the views of the ancient Greeks

Groundwork

• Make copies of Greek Cosmologies (one for each student).

For the teacher

The Story of Science: Aristotle Leads the Way, chapters 9 -13
Teacher’s Quest Guide
Greek Cosmologies

For each student

The Story of Science: Aristotle Leads the Way, chapters 9 -13
Student’s Quest Guide
Greek Cosmologies
Classwide Activity

Complete a web

1) Remind students that they have studied the views of several important Greeks from the sixth through third centuries B.C.E.

2) Display the transparency web *Greek Cosmologies* and distribute copies to students.

3) Working as a class, students use their text and *Student’s Quest Guide* to find information to complete the web.

4) Students enter information on their copies of the web individually as you enter it on the transparency.

5) When the class has completed the web, each student drafts a topic sentence for an essay comparing or contrasting two cosmologies to be written on the assessment day. Check topic sentences to make sure each student has an accurate and workable sentence for the assessment essay.

Assessment III

Use vocabulary to write brief essay answers to questions

Help students devise study activities to review significant people, vocabulary terms, and concepts from Unit II.
# Assessment II KEY

## Greek Cosmologies

<table>
<thead>
<tr>
<th></th>
<th>Pythagoras</th>
<th>Aristotle</th>
<th>Aristarchus</th>
</tr>
</thead>
<tbody>
<tr>
<td>universe</td>
<td>orderly, best understood through mathematics</td>
<td>eternal, unchanging universe</td>
<td>estimated the size of the Moon and its distance from Earth</td>
</tr>
<tr>
<td>shape of Earth</td>
<td>sphere</td>
<td>sphere</td>
<td>sphere</td>
</tr>
<tr>
<td>place of Earth</td>
<td>Earth, Sun, and planets circle a large fireball.</td>
<td>Sun, stars, and planets circle an unmoving Earth at center of universe.</td>
<td>Earth orbits a stationary Sun.</td>
</tr>
<tr>
<td>other beliefs</td>
<td>Numbers have special attributes, should be worshiped.</td>
<td>four elements: earth, air, fire, water</td>
<td>Earth has an inclined axis.</td>
</tr>
</tbody>
</table>
Rapping It Up: A Greek View of the Universe

The Greeks of old liked to spend their days
Looking at the world in philosophical ways.
Trying to decide how the cosmos was aligned
Charting out the paths of the stars in the sky.

Using only their eyes, they were right about much
But that geocentric plan was a bit out of touch.
P. the mathematician was brilliant but odd.
He knew about numbers but worshiped them as gods.
Heard music in the planets, earned nothing but jeers
When he told his fellow thinkers that the Earth was a sphere.

Democritus studied elements though he couldn’t prove
That tiny, solid atoms are perpetually on the move.
Aristotle’s great mind all the Earth surveyed
Thought the heavens perfect and of aether made.
He tried to unravel that old universal riddle.
His view of the cosmos put the Earth in the middle.

Alone among the Greeks Aristarchus was the one
Who surmised that the Earth was on an axis and spun
Causing winter and summer, sunset and sunrise.
He was 2,000 Earth-years ahead of his time.

He put the Sun in the center with the planets all around
But no one would believe him ‘til Copernicus found
His papers—so give credit where credit is due
Those Greeks were a brainy and amazing crew!
Assessments

Assessment I

Teams trade games with other teams and play according to the rules defined in lesson 8. Circulate among the teams as students play to assist and answer questions. Take notes during play on the quality and accuracy of each set of playing cards and collect the sets at the end of play to give each creating team a group grade.

Alternate Assessment I

Students complete and perform their raps for the class. Each student submits a clean copy of the team’s rap.

Grading

Students receive a group grade. Award points for every person, date, event, and circumstance that they accurately mentioned in their rap. They may also receive points for creativity and skill in putting the information in a reasonably smooth rap form and for the polish of their performance.

Assessment II (open book)

Working independently, students use the web and topic sentence from the previous lesson to write a four-paragraph essay comparing or contrasting two cosmologies. Students may use chapters 9-13 of the text and the Student’s Quest Guide for additional information. Remind students to end their essay with a concluding sentence.

Assessment III

Groundwork
(closed book)

- Make copies of Unit II, Assessment III For each student.
Assessment III KEY

A. Underline the correct answer.

1) This ancient Greek believed everything in the world could be explained through mathematics. “All is number,” he said.
   Democritus
   Aristotle
   Eratosthenes
   **Pythagoras**

2) A number that cannot be turned into a ratio of two integers is
   - an irrational number
   - a rational number
   - a radius
   - a Pythagorean Theorem

3) This Ionian believed that atoms are the smallest substance in the universe that can’t be cut or destroyed and is basic to everything else.
   - Democritus
   - Aristotle
   - Pythagoras
   - Socrates

4) This scientist/philosopher looked for beauty, truth, and clarity.
   - Aristotle
   - **Plato**
   - Socrates
   - Anaxagoras

5) This scientist/philosopher believed the Sun, stars, and planets were attached to perfect, hard, crystal spheres.
   - Aristotle
   - Plato
   - Eratosthenes
   - Democritus
6) The Pythagorean Theorem is
\[ \pi = 3.14 \]
\[ e = mc^2 \]
\[ a^2 + b^2 = c^2 \]
the Golden Ratio or 1.618

7) When planets appear to move backward, this optical illusion is called
empirical knowledge
diurnal motion
aether
retrograde motion

8) The divine, everlasting element that Aristotle believed the heavens were made of was called
aether
papyrus
the zodiac
crystal spheres

9) In the cosmology of _______________, a moving Earth orbits a stationary Sun.
Aristotle
Aristarchus
Anaxagoras
Plato

10) ___________ figured out the size of the Moon, its distance from Earth, and that the Sun rotated on an inclined axis.
Aristarchus
Ptolemy
Aristotle
Pythagoras
B. Short Answer

1) Explain the significance of the Earth's tilt. Use the following vocabulary in your answer.
   inclined axis     hemisphere     direct sunlight

   Because the Earth revolves on an inclined axis, half of the globe receives weaker, indirect rays part of the year. When the Northern Hemisphere receives weaker rays, it experiences winter. It receives more direct sunlight during summer.

2) Contrast the philosophies of Plato and Aristotle. Use the following vocabulary in your answer.
   synthesizer     principles of logic     life of the mind
   ideal forms     philosophy and ethics     biology, astronomy

   Plato was interested in ideal forms. Aristotle was a scientist/philosopher who was interested in the world around him. He was a synthesizer who organized information. He developed principles of logic. While Plato and his followers focused on the life of the mind and ideal forms, Aristotle and his followers tried to understand the world around them. While Plato focused on philosophy and ethics, Aristotle studied biology, astronomy, and other subjects.

3) Describe Aristotle's cosmology. Use the following vocabulary in your answer.
   Earth     Sun     orbits     aether     elements

   Aristotle believed the Sun, Moon, and planets circled the Earth, and that the Earth stood still at the center. The stars and planets in his cosmology follow perfect, circular orbits and are made of a divine element called “aether.” The planets, Sun, and stars are attached to perfect, clear crystal spheres.
C. Vocabulary
Use the following vocabulary words to fill in the blanks.

void  meticulous  logic  aether
nucleus  theorum  austere
synthesizer  hypotenuse  philosophy

1) meticulous  careful about details
2) void  empty space, nothingness
3) nucleus  mass at the core of something
4) logic  the science of correct reasoning
5) hypotenuse  the longest side of a triangle
6) theorum  a formula or equation expressing a natural law
7) austere  severely simple; strict
8) synthesizer  someone or something who combines separate elements into one complex whole

D. Short Essay
Write a letter nominating Aristarchus for the Scientists Hall of Fame. What information will you give about his achievements? Mention at least three important concepts he developed.

Dear Hall of Fame:

I would like to nominate Aristarchus, who lived in the third century B.C.E. He figured out that the Earth revolves around a stationary Sun. While Aristotle believed the Earth was at the center of the universe, Aristarchus knew this was not true. He also figured out the size of the Moon and its distance from Earth. He knew that the Earth rotated on an inclined axis, causing day and night and seasons. He used his mind to figure out a great deal even though he lived a long time ago.

Thank you for considering my request.

Sincerely,