SCIENCE

EARTH and SPACE

Second Edition

abeka
SCIENCE/HEALTH SERIES

Science: Earth and Space

Second Edition

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Cataloging Data
Science, earth and space- -2nd ed.
428 p. : col. ill. ; 26 cm
Includes index.
1. Science—Study and teaching (Secondary).
II. Abeka Book, Inc.

Library of Congress: Q161.2.S25 2018
Dewey System: 507

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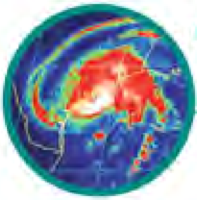

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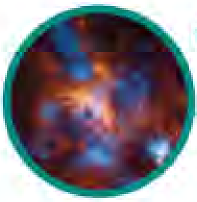

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How To Use This Text

Science: Earth and Space has many features designed to make your study of earth and space science interesting and beneficial.

Interesting Content

The Table of Contents gives you an overview of what you will study this year. After learning basic principles about earth and space science and the methods scientists use to discover facts about nature, you will study the structure and components of the earth. You will see how the evidence from rocks and fossils supports the biblical account of Creation. Next, you will study Earth's oceans, atmosphere, and weather. You will see how God's awesome power is revealed in the heavens and the universe. Finally, you will learn how to better fulfill man's responsibility to care for the environment God created.

Study Aids

Throughout the text, the most important terms and concepts are marked using bold or italic text.

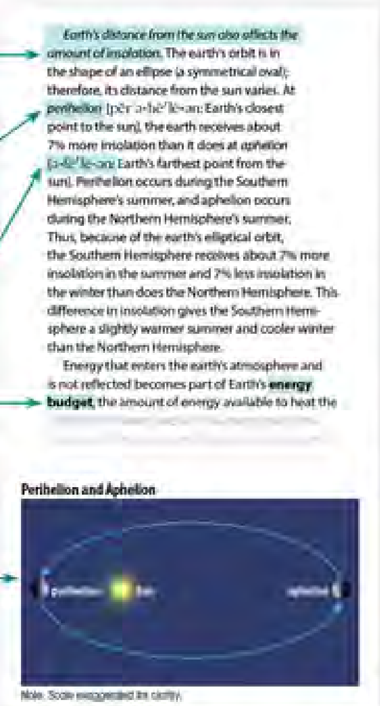
A sentence or phrase in italics is an important concept or definition of which to take particular note.

Italic terms guide you in following the logic of the text or highlight connections to previous chapters.

Pronunciations of unusual or unfamiliar words are given at first use; a pronunciation key is on p. 398.

Mastering key terms in bold will help you understand concepts and prepare for quizzes and tests.

Illustrations enhance interest and understanding.



Earth's distance from the sun also affects the amount of insolation. The earth's orbit is in the shape of an ellipse (a symmetrical oval); therefore, its distance from the sun varies. At **perihelion** [pĕr′ ə·hē′ lē·ən: Earth's closest point to the sun], the earth receives about 7% more insolation than it does at *aphelion* [ə·fē′ lē·ən: Earth's farthest point from the sun]. Perihelion occurs during the Southern Hemisphere's summer, and aphelion occurs during the Northern Hemisphere's summer. Thus, because of the earth's elliptical orbit, the Southern Hemisphere receives about 7% more insolation in the summer and 7% less insolation in the winter than does the Northern Hemisphere. This difference in insolation gives the Southern Hemisphere a slightly warmer summer and cooler winter than the Northern Hemisphere.

Energy that enters the earth's atmosphere and is not reflected becomes part of Earth's **energy budget**, the amount of energy available to heat the

Perihelion and Aphelion

Note: Scale exaggerated for clarity.

Pronunciations are also given for many terms. In the back of the book, you will find a **Glossary** of key terms and definitions (p. 398) and an **Index** listing all references to the major topics (p. 418).

Feature Articles

This text includes many articles that will enhance your study of science. "A Closer Look" articles present detailed information of various interesting topics to aid your understanding of the text. "Creation Clip" boxes present specific and interesting examples of God's design in nature.

There are also activities throughout the book. "Check It Out" and "Science Investigation" activities can be completed during the lesson to illustrate concepts from the text. "Backyard Scientist" are activities and projects that can be completed outside the lesson to help you learn about nature by exploring it.

Section and Chapter Reviews

Section reviews will be useful as you read the text and prepare for quizzes. **Chapter reviews** will help you study for tests. Each chapter review consists of four sections: Define, Identify, Explain, and Apply.

Accurate, Detailed Illustrations

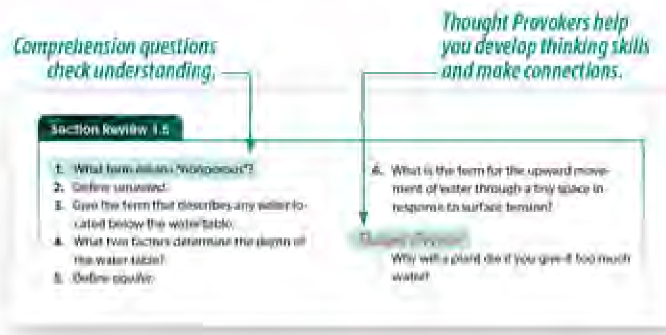
Every photograph and diagram in this book was chosen to enhance your interest in and understanding of the written text. As you read the text, pay close attention to the illustrations; match them with the text material and read the captions and labels. If the illustration is showing a process, trace the process as you read the text.

Christian Perspective

The most important feature of this science textbook is its Christian perspective. The authors believe that the world and all things in it were created exactly as explained in the Bible (Gen. 1, 2) and that the order found in creation is the result of God's wonderful design (Psa. 104). Most of the world's greatest scientists—men like Galileo, Sir Isaac Newton, Robert Boyle, Lord Kelvin, Michael Faraday, Gregor Mendel, Louis Pasteur, Johannes Kepler, and Joseph Lister—worked from this perspective. It is the authors' desire that as you gain a deeper knowledge of the living creation, you will be drawn closer in a personal relationship with the Creator.

Study Tips for Science

- Do your homework right after school, while what you learned is still fresh in your mind.
- Review daily.
- Note key terms and ideas by highlighting them or by recording them in a notebook.
- Summarize or outline the text in your own words.
- Make flashcards of terms and definitions.
- Write review questions and answers. Swap with a friend and answer each other's questions.



O give thanks

unto the LORD; for he is good:
for his mercy endureth for ever.

O give thanks

unto the God of gods:
for his mercy endureth for ever.

O give thanks

to the Lord of lords:
for his mercy endureth for ever.

To him who

alone doeth great wonders:
for his mercy endureth for ever.

To him that

by wisdom made the heavens:
for his mercy endureth for ever.

To him that

stretched out the earth above the waters:
for his mercy endureth for ever.

To him that

made great lights:
for his mercy endureth for ever:

the sun to rule by day:
for his mercy endureth for ever:

the moon and stars to rule by night:

for his mercy
endureth for ever.

Psalm 136:1–9

Introduction to Science

Key Concepts

- *scientific method*
- *scientific reasoning*
- *soil characteristics*
- *soil nutrients*
- *nitrogen cycle*
- *ground air and water*

1.1 Using the Scientific Method

At the beginning of time, God created both the beautiful, fascinating world that we live in and the entire universe that surrounds us. Although some aspects of God's creation are easy for us to understand, God purposely designed most of His universe so that we need to study it in order to better understand it. According to Proverbs 25:2–3, "It is the glory of God to conceal a thing: but the honour of kings is to search out a matter. The heaven for height, and the earth for depth, and the heart of kings is unsearchable." Through observation and measurement, we can begin to understand the patterns that God has placed within the natural world.

Science is the study of the matter and movement of God's physical creation. **Matter** is the substance of the physical world; anything that occupies space or has substance is matter. It includes everything that we observe, such as animals, plants, rocks, stars, clouds, minerals, and our own bodies. Matter is constantly in motion—growing, moving, boiling, falling, crumbling, decaying, expanding, and more!

An Orderly Operation

To scientifically investigate the wonders of God's physical creation, we must not only observe matter with keen eyes and sharp minds but also ask probing questions about it. Then, with patience and precision, we must conduct experiments and carefully examine the results, searching for sensible answers to our questions.


volcano


geyser


tornado

In this chapter, you will learn the steps of the scientific method and will have opportunities to apply the scientific method to various questions in **pedology** [pĭ·dŏl′ə·jē], the study of soil. Applying the steps of the scientific method throughout the remaining chapters will enable you to make fascinating discoveries and to gain a greater knowledge of the topics covered.

The **scientific method** is an organized way for scientists to gather and pursue scientific knowledge. *The three main components of the scientific method are hypothesizing, observing, and experimenting.* **Hypothesizing** is speculating, or thinking seriously, about the objects and events of nature and formulating a sensible explanation, or **hypothesis** [hī·pŏth′ĭ·sĭs; plural hypotheses: hī·pŏth′ĭ·sēz′]. **Observation** involves gathering **data** (facts) about nature in an orderly way. **Experimentation** is methodically testing hypotheses. Data gained through observation and experimentation is *empirical* [ĕm·pĭr′ĭ·kəl: from experience] *data*.

These three components are often carried out in six basic steps:

1. State the problem.
2. Gather information about the problem.
3. Formulate a hypothesis.
4. Test the hypothesis by experimentation.
5. Record and analyze the experiment.
6. State the conclusions.

Although these steps usually work best in this sequence, the scientific method does not always follow a particular order. For example, a scientist may get inconclusive results or he may test his hypothesis and realize that it does not work. He then has to go back to the problem, gather more information, and create another hypothesis to test. A scientist may need to reuse these steps several times before reaching a definite conclusion.

After many experiments and observations are completed, scientists may use their conclusions to formulate a **theory**, a way of explaining an object or event by using a set of facts. If a theory has never been proven false, scientists will call it a **law**.

Applying the Six Steps

When a scientist has a problem to solve, he uses the steps of the scientific method. Suppose you are growing a vegetable garden. When visiting a nursery to get seed, you observe that some seedlings are planted in soil that appears to have several different textures mixed together. A nursery worker tells you that the soil is a mixture of potting soil, sand, and perlite (a volcanic glass used to prevent soil compaction). After learning this, you begin wondering if choosing the right soil composition will allow you to harvest your vegetables sooner.

1 **State the problem.** The first step in a scientific investigation is to state the problem to be solved. Your problem is that you want your vegetables to be ready for harvest sooner.

2 **Gather information** about the problem. You have already gathered some information from your visit to the nursery. You may read printed or online gardening resources to find out what factors affect plant growth. You will also consider things you already know that might be relevant to the problem.

3 **Formulate a hypothesis.** From the information you gathered, you are ready to formulate a hypothesis. You suspect that different types of soil hold different amounts of water and will thus affect plant growth. Therefore, your hypothesis is that adding sand and perlite to potting soil will affect the rate at which plants grow.

For a hypothesis to be scientific, there must be some situation that, if it occurs, would prove the hypothesis false; this property of a hypothesis is called **falsifiability**. Your hypothesis is falsifiable because it would be proven false if, after properly testing the hypothesis, you found that soil composition does not affect plant growth rates.

4 **Test the hypothesis** by designing and performing an experiment. For your experiment, you choose to test 100% potting soil; a mixture of 90% potting soil and 10% sand; a mixture of 90% potting soil and 10% perlite; and a mixture of 90% potting soil, 5% sand, and 5% perlite. You have one group of pots for each mixture, with six pots in

each group. You plant several broccoli seeds in each pot. (If more than one seedling sprouts in a pot, you cut all except the first so they do not grow.) Every day for 6 weeks, you check the pots and measure the height of the seedlings. You also calculate and graph the average height of the plants in each group.

Every experiment has many *variables*—factors that you as an experimenter can control. There are three important types of variables in any experiment. These variables are determined before you begin to experiment. A **dependent variable** is a factor that is observed to determine the results of the experiment. Every experiment must have one or more dependent variables, which come from the problem you are trying to solve. In your experiment, the dependent variable was the average height of the seedlings in each group.

The **independent variable** is the factor that you change to test your hypothesis. *An experiment should have only one independent variable;* this helps ensure that any significant difference in the dependent variable between groups is due to the independent variable. In your soil experiment, the independent variable was the substance added to the potting soil.

All variables other than the dependent variable and independent variable should be **controlled variables**, which are the same in all groups. Factors like air temperature, kind of seeds, amount of water received, and amount of sunlight were controlled variables in your experiment.

Every experiment must have at least two different groups; *by comparing the results of the different groups, you gain empirical evidence as to whether your hypothesis is correct or not.* Your experiment had three **experimental groups**, the groups on which a test is performed. Every experimental group will have a different value

Scientific Habits

Several habits characterize an effective scientist. As you study science and perform your own scientific investigations, you should try to develop these habits yourself.

Curiosity—*An effective scientist is curious about the natural world and wants to learn more about it.*

Creativity—*An effective scientist uses creativity to develop hypotheses and design new experiments.*

Orderliness—*An effective scientist must be orderly in many areas, from keeping track of control and experimental groups in experiments to recording and presenting experimental results and conclusions.*

Intellectual honesty—*An effective scientist is honest about his own mistakes and about observations that do not support his hypotheses; he also gives proper credit to the ideas and research of others instead of claiming them as his own.*

Acceptance of uncertainty—*An effective scientist knows that the results of an experiment may not always allow him to draw a conclusion about his hypothesis; he will accept this uncertainty until the evidence allows making a definite conclusion.*

Skepticism—*An effective scientist is skeptical of scientific ideas, both his own and those of others, and will not accept them unless they are supported by sufficient evidence.*

Openness to new ideas—*An effective scientist is willing to listen to and carefully consider the scientific ideas of others; he does not reject others' ideas merely because they disagree with his own views.*

As Christians, we must also remember that the Bible is God's perfect Word. We can always trust what the Bible says about science and must reject any scientific ideas that contradict the Bible.

for the independent variable; your experimental groups were the three groups that had sand or perlite added to the potting soil. An experiment may also have a **control group**, a group in which the independent variable is absent; this group is not tested but is used as a standard for comparison. In your experiment, the control group was the group planted in plain potting soil, without any sand or perlite added. Not every experiment will need a control group; but an experiment without a control group must have two or more experimental groups that are compared to each other.

5 **Record and analyze** any changes during the experiment and record the results of the experiment. Document the variables in each experiment. Did you get the results that you expected? If your results came out differently than you expected, consider if some variable that you did not consider affected the outcome. Perhaps you found that the original hypothesis was wrong—that plants will grow at the same rate even in different mixtures of potting soil, sand, and perlite. You may wish to formulate and test another hypothesis. Also consider changes that you can suggest for someone else who tries the experiment.

6 **State the conclusions.** Experiments with clear, complete, and accurate records may provide information for others to use in further research and may help them acquire a better understanding of God's creation.

Tackle This

Suppose that for a STEM fair project, you designed an experiment to determine if various materials added to soil will promote worm health. The worms in your control group are in a container of plain potting soil, given 60 mL (2 oz) of water every 5 days, and stored at a constant temperature of 20°C (68°F).

For the following experimental groups, (1) determine whether each condition for the experiment is an independent or controlled variable, and (2) determine which experimental groups correctly follow the scientific method.

Experimental Group 1

1. soil + ground-up granite
2. 60 mL of water every 5 days
3. temperature of 20°C

Experimental Group 2

1. soil + wood mulch
2. 60 mL of water every 5 days
3. temperature of 20°C

Experimental Group 3

1. soil + sand
2. 60 mL of water every 5 days
3. temperature of 30°C (86°F)

Experimental Group 4

1. soil + ground-up granite
2. 300 mL (60 oz) of water every 5 days
3. temperature of 20°C

A Closer Look

Engineering Design

Technology is the use of science to solve practical problems. The development of technology is *engineering*. Just as scientists use the scientific method to investigate the laws of nature, engineers use the **engineering design process** to develop technology. Even if you do not become a professional engineer, you will often need to use the engineering design process as you try to figure out new and better ways of doing things.

The engineering design process can be divided into six main steps:

1. State the problem to be solved.
2. Determine the criteria and constraints of the problem.
3. Research and develop possible solutions to the problem.
4. Choose a design and make a detailed plan.
5. Build and test a prototype.
6. Analyze the prototype and improve the design.

Like the steps of the scientific method, the order of these steps will sometimes vary. An engineer will probably repeat some of the steps several times before finishing the design.

Suppose Jasmine wants to figure out a way to make brownies while on a camping trip. She has already figured out how to bring the ingredients; but because of dry weather, fires are not allowed where she will be camping. Jasmine decides to use the engineering design process to come up with a way to bake her brownies without risking starting a wildfire.

❶ **State the problem to be solved.** Jasmine states the problem as "How can I bake brownies in the wilderness without using something that can start a fire?"

❷ **Determine the criteria and constraints of the problem.** In engineering design, the **criteria** (sing. criterion) are the minimum characteristics that a design must have to function at all. The function of Jasmine's design is to bake brownies. She decides that, to perform this function, her design needs one criterion: it must be able to heat the brownie batter to at least 120°C (250°F) and maintain that temperature for several hours, until the brownies are baked. But not every device that meets this criterion will solve Jasmine's problem. She must also define **constraints**, which are any characteristics (other than the criteria) required to solve the problem. Since Jasmine must carry either the completed device or the needed materials with her on the camping trip, the design must be small and lightweight. To avoid starting a wildfire, the design cannot involve an open flame. Because Jasmine has a limited budget, the materials must be relatively inexpensive.

❸ **Research and develop possible solutions to the problem.** Jasmine researches to find out how others have solved problems similar to hers and brainstorms to come up with her own solutions. She considers whether each possible solution meets the criterion and constraints. She first looks at commercially manufactured camping stoves and ovens; these meet the design criterion (they are able to bake brownies), but they do not meet the constraints, either having an open flame or costing more than Jasmine can afford. She finds an article discussing solar cookers, which heat food using sunlight. According to the article, a small solar cooker can heat food to 120°C, is lightweight, and can be inexpensive to make. After researching different types of solar cookers, Jasmine sketches plans for a few different solar cookers that she can build and considers how each cooker would match the criterion and constraints.

❹ **Choose a design and make a detailed plan.** After reviewing her proposed solar cooker designs, Jasmine chooses the design

(cont.)

that she thinks will best meet the criterion and constraints. The chosen design may combine ideas from several of the designs she considered. She makes a detailed drawing of this design, showing exactly how she plans to build a solar cooker, including the sizes of each component. Her design is a solar oven made of two cardboard boxes, one larger than the other. The smaller box is inside the larger box with crumpled-up newspaper between them for insulation. Four large pieces of cardboard, covered with aluminum foil, are mounted on the top of the larger box to reflect the sun's light into the smaller box. A clear piece of plastic sheeting will be a lid, allowing sunlight into the box while keeping hot air inside.

❺ **Build and test a prototype.** A **prototype** is a model of a design (or some part of a design) that is used for testing. For a complex design, several different prototypes may be built, each intended to test a different aspect of the design. Since Jasmine's design is simple, she builds just a single prototype, which is a full-scale working model of her solar cooker. To test the prototype, she places the oven in a sunny location with an oven thermometer inside and checks the temperature periodically.

❻ **Analyze the prototype and improve the design.** After performing her tests, Jasmine analyzes the prototype to see if the design meets the criterion and constraints. She finds that it did meet the constraints: it does not use an open flame; the materials are inexpensive; and a disassembled oven is small enough and light enough to carry on her trip. However, it did not meet the criterion of heating to 120°C. Now, Jasmine needs to consider *why* the design failed and either modify her design or choose a new one; then she will need to either modify her prototype or build a new prototype. Looking back at her research, she realizes that most solar ovens have black interiors to absorb the sunlight. She modifies her design to include black construction paper lining the inside of the smaller box and makes this change to the prototype. Finally, Jasmine tests the prototype again and finds that it does reach 120°C.

The cycle of testing, improving, and retesting the design continues until the design satisfies the criterion and constraints. At this point, the design is considered complete. Of course, there may be other ways the design can be improved; but making these improvements starts the engineering design process again, with a new problem, criteria, and constraints. Jasmine may decide she wants her oven to be waterproof; this becomes her new problem. She has the same criterion as before but has the added constraint that the oven must be waterproof. She will continue the engineering design process, either adapting her existing design or choosing a completely new design.

Section Review 1.1

1. Define *science.*
2. What is the study of soil?
3. What is a scientific law?
4. What does it mean to say that a hypothesis is falsifiable?
5. Explain the difference between an experimental group and a control group.
6. What is a prototype?

Science Investigation

Adult supervision required!

Cabbage Chemistry

A *pH indicator* is a substance that changes color depending on whether it is in an acidic or basic substance. In this investigation, you will make your own liquid pH indicator by boiling red cabbage leaves. To determine if soil is acidic or basic, you need to know how the liquid pH indicator changes colors in the presence of acids and bases. You will use household items that are known to be acids and bases to see the changes in your pH indicator before testing soils for their acidity or basicity. In this experiment, vinegar or lemon juice will be the known acid; and household ammonia will be the known base.

Materials

- Distilled water
- Two large beakers (or a saucepan and a plastic bowl)
- Red cabbage leaves
- Hotplate or stove
- Strainer
- Medicine dropper
- Two small beakers or glass containers
- Vinegar or lemon juice
- Household ammonia
- Four or five watch glasses or small plates
- Garden lime
- Peat moss
- Two or three soil samples (If possible, use the samples from Science Investigation: A Stirring of the Soil [p. 14].)

STEP 1 Place 250 mL (1 cup) of distilled water in a large beaker or a saucepan. Tear up several red cabbage leaves and add them to the water. Bring the water and cabbage leaves to a boil on a hotplate or stove; gently boil the leaves for 5–10 minutes.

STEP 2 Turn the heat off and allow the water and leaves to cool to room temperature. Pour the mixture through a strainer, catching the red cabbage juice in a second beaker or a plastic bowl. **Note:** If you are preparing cabbage juice more than a day before you will be using it, store it in a covered container in the refrigerator.

STEP 3 Place a small amount of vinegar or lemon juice in a small beaker or other small glass container; place a small amount of household ammonia in a second small beaker. Use a medicine dropper to add a few drops of cabbage juice to each container. (Be careful not to get the dropper in the vinegar, lemon juice, or ammonia.) Observe how the pH indicator changes in the presence of an acid and of a base. Record your observations of the color change in the pH indicator.

STEP 4 Place a small amount of garden lime on a watch glass or small plate. Place a small amount of peat moss on another watch glass or small plate. Drop a few drops of pH indicator onto each sample, and record your observations.

STEP 5 Repeat step 4 with your soil samples, using clean watch glasses or plates. Record your observations.

Questions

1. What color did your pH indicator change in the presence of an acid? Of a base?
2. Is lime acidic or basic? Is peat moss acidic or basic?
3. Compare your results for this investigation with the results from Science Investigation: A Stirring of the Soil (p. 14). Did you observe a relationship between soil acidity and basicity and the physical composition of the soil?

Section Review 1.3

1. What two kinds of material make up soil?
2. Besides holding large amounts of water, what job does humus do in soil?
3. Name the top two layers of soil.
4. Name the process by which rocks are broken down into soil.
5. What determines the texture of soil?
6. Give the functions of sand in soil.
7. What is loam?
8. What can color tell us about soil?
9. How do chemists express the degree of acidity or basicity of a substance?

1.4 Soil Nutrients

The mineral and organic materials of the soil together supply **nutrients** (nourishing substances) for plants. *The three most important mineral nutrients for plants are nitrogen, phosphorus, and potassium.* Because plants remove these three *elements* (substances composed of only one type of atom) from the soil as they grow, these nutrients are called the **primary plant food elements**. As plants die and decompose, they add these three elements back into the soil.

Fertilizer Composition

Since some crops require more nitrogen, phosphorus, and potassium than are naturally added to the soil, farmers and gardeners often add commercial fertilizers designed specifically to replenish the primary plant food elements. Each element may be applied separately or as a combination in a mixed fertilizer containing the three elements. In fertilizers, phosphorus is generally in the form of **phosphates** (a group of chemicals containing the element phosphorus bonded to oxygen and other elements), and potassium is generally found as **potash** [pŏt′ăsh′: potassium oxide, a chemical consisting of two potassium atoms bonded to an oxygen atom]. Nitrogen can be in any of several different nitrogen-containing chemicals.

Commercial fertilizers indicate the percentages of these primary elements in alphabetical order on the package. For example, a homeowner may purchase fertilizer designed specifically for grasses. On the label, he might find the numbers "20-2-2." This fertilizer contains 20% nitrogen, 2% phosphates, and 2% potash. Fruit-bearing orchard trees need a 3-18-18 fertilizer (3% nitrogen, 18% phosphates, and 18% potash). Most vegetable gardens would use a balanced 14-14-14 fertilizer.

Necessary Nitrogen

Nutrients in the soil affect the growth of plants. **Nitrogen** stimulates rapid growth of leaves, giving plants a rich green color. Its effects are obvious—plants look strong and healthy when they have adequate nitrogen. Insufficient amounts of nitrogen will restrict growth and change leaves to a pale green or yellow color. Because nitrogen also stimulates stem growth, too much nitrogen causes the plant to grow so fast above the ground that the root system cannot absorb sufficient minerals to keep up with the plant's needs. As a result, the plant is less resistant to diseases and produces fewer fruits.

"Around the world." God designed a system to recycle nitrogen. In the **nitrogen cycle**, nitrogen is moved from the air to the soil to be used by plants and then returned to the atmosphere to be used again. Although there is plenty of nitrogen in the air, plants cannot use the atmospheric gas until it

Check It Out

Adult supervision required!

Water on the Rise

To see the effects of capillarity in the transport tubes of a plant, fill *two beakers or glasses* about half full with *water*. Add a few drops of *red food coloring* to one beaker and an equal amount of *blue food coloring* to the other beaker, using a *stirring rod or spoon* to mix each color of dye with the water.

Next, place a *large stalk of celery* onto a *cutting board* and use a *knife* to cut off about 2.5 cm (1 in) of the lower end of the stalk. Starting from the bottom, make a vertical cut that extends halfway up the stalk. Set the two beakers of water side by side and lower a section of the stalk into each beaker. After a few hours, what color is each cut section of the stalk? Did the colors blend where the stalk was whole?

Place the celery on the cutting board again. This time, cut across the top of the stalk and look at the freshly cut surface. Do you see the colored dots along the edges of the stalk? Each dot represents a transport tube. Try putting a *drinking straw* into one of the beakers of water; why does the water not rise to the top of the straw as it did in the transport tubes of the celery?

Section Review 1.5

1. What term means "nonporous"?
2. Define *saturated.*
3. Give the term that describes any water located below the water table.
4. What two factors determine the depth of the water table?
5. Define *aquifer.*
6. What is the term for the upward movement of water through a tiny space in response to surface tension?

Thought Provoker

Why will a plant die if you give it too much water?

CHAPTER 1 REVIEW

Define

1. science
2. matter
3. pedology
4. scientific method
5. hypothesis, data
6. criterion, constraint
7. inference
8. proposition, hypothetical proposition
9. repeatability, reproducibility
10. post hoc fallacy
11. organic mineral, mineral material
12. atom, molecule
13. mass, weight, density
14. weathering
15. bedrock

16. loam
17. pH scale
18. phosphates, potash
19. element, compound
20. nitrogen-fixing bacteria
21. saturated, groundwater
22. aquifer, artesian well
23. capillarity

Identify

1. the three main components of the scientific method
2. the two main categories of reasoning
3. the reusing of old materials
4. the top two soil horizons
5. the type of chart used to describe soil colors
6. the three primary plant food elements
7. the upper surface of groundwater

Explain

1. Explain the difference between independent variables and dependent variables.
2. Why should only one independent variable be used in an experiment?
3. Explain the difference between experimental groups and control groups.
4. Explain how a prototype is used in the engineering design process.
5. What two methods can be used to make a deductive inference from a hypothetical proposition?
6. What is the method of difference?
7. Why can inductive reasoning never prove a hypothesis beyond all doubt?
8. Why is humus important?
9. What determines the texture of soil?
10. Explain the difference between sand, silt, and clay.
11. What factors affect soil color?
12. How does soil pH affect the growth of plants?
13. What primary plant food element is essential for cell division and promotes maturation?
14. Why are pore spaces in soil important to plants?
15. Why may soil above the water table still be damp?

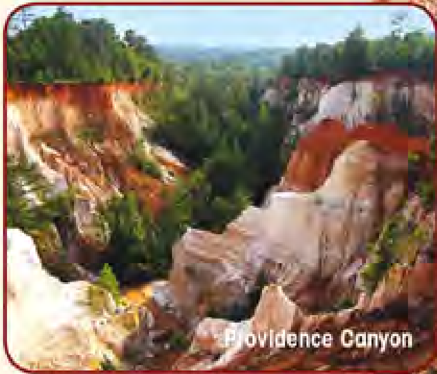
Apply

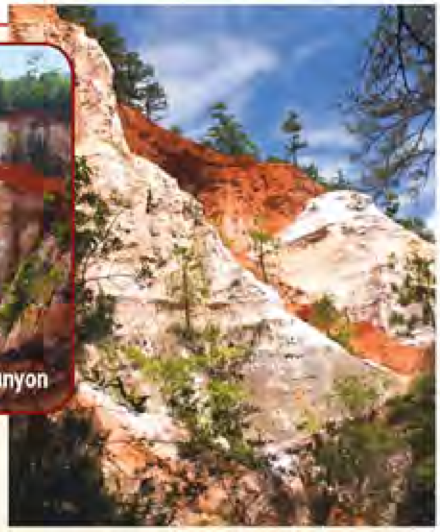
1. Why must a scientific hypothesis be falsifiable?
2. A scientist wants to learn the effect that different soil mixtures have on airflow through the soil. What is one hypothesis that he could test? What should be the independent and dependent variables in his experiment?
3. If a substance has a pH below 7, it is acidic. Lemon juice has a pH below 7. What form of deductive reasoning is used to infer that lemon juice is acidic? How can you tell?
4. Explain why the nitrogen cycle is important for plants, animals, and humans.
5. Contrast nitrifying bacteria and denitrifying bacteria.
6. Explain what happens to a plant if the ground is saturated for too long.
7. Why must an aquifer that feeds an artesian well be below an impermeable rock layer?

A Closer Look

Catastrophic Canyon Formation

A *canyon*, or *gorge*, is a deep valley that has steep, rocky sides and was carved out by flowing water. One of the most famous canyons, the Grand Canyon, is a magnificent and breathtaking sight, but it is also the site of much debate. Evolutionists and creationists both believe that the Grand Canyon formed through water erosion, but they hold to different views on how long it took. Evolutionists believe the Grand Canyon has been forming very slowly over a period of millions of years; many creationists, on the other hand, believe that most of the canyon quickly formed sometime after the Genesis Flood. Several smaller canyons provide evidence for a quick-forming Grand Canyon.


Providence Canyon



Providence Canyon in southwest Georgia is also called "Georgia's Little Grand Canyon." This canyon is actually a series of 16 canyons that began forming in the mid-1800s due to poor farming practices that encouraged erosion. The canyons are now up to 46 m (150 ft) deep, 180 m (600 ft) wide, and 400 m (1300 ft) long; the canyons are still growing, especially in width, as rainfall continues to erode into the soil and strata.

The Burlingame Canyon in Washington State formed in 1926 when engineers diverted abnormally large amounts of water from an irrigation canal into a small ditch that led to a stream. Within six days, the large amounts of water had eroded the ditch into a canyon up to 37 m (120 ft) deep, 37 m wide, and 460 m (1500 ft) long. The water had removed over 150,000 m^3 ($5,300,000 ft^3$) of sediments.


The Grand Canyon

In 2002, Canyon Lake Gorge formed when Texas's Canyon Lake overflowed and sent huge amounts of rushing water into a valley. The immense water flow (up to 2000 m^3/s or 70,000 ft^3/s) carved into the valley's limestone and created a gorge in just three days. After the water flow had stopped, scientists discovered that the newly formed gorge was 2.4 km (1.5 mi) long and up to 24 m (80 ft) deep.

These three smaller canyons give scientists a glimpse of just how fast the Grand Canyon could have formed if there was enough rapidly flowing water. For creationists, this supports the fact that the world's geologic features, including the Grand Canyon, have formed within the past 6000–8000 years. The large amounts of water needed for the Grand Canyon probably came from either the Flood or the Ice Age that occurred shortly after the Flood.

Dig Deeper

The flowing water of the Niagara River used to erode Niagara Falls at a rate of 1–1.5 m (3.3–4.9 ft) per year. Now, due to antierosion methods and the use of the water for power, the rate of erosion has slowed.

A river's course. When a river reaches land that is more level, it slows down considerably and becomes wider. Numerous streams called **tributaries** continue to feed into the river at various points along its course, increasing the amount of water that it carries. Large flatland rivers like the Mississippi River and Egypt's Nile River grow much larger in the spring when they pick up huge amounts of water from melting snow and ice upstream. Some, like the Nile, actually overflow their banks. The level or nearly level land that borders a river and is covered by river water in flood time is called the **floodplain**. When the river overflows its banks, floodwater spreads over the floodplain, depositing enormous amounts of sediment from upstream. Because of this annual deposit of new soil, floodplains are especially fertile and usually extensively farmed.

When a river overflows its banks and extends onto the floodplain, the waters on the floodplain are sluggish, while the waters in the river channel maintain a swift current. This difference in water flow causes the river to drop some of its sediments along the edges of the river's channel, forming natural ridges called **levees.** Similar manmade levees are sometimes constructed to confine a river to its channel and prevent extensive flooding.

Dig Deeper

Some of the natural levees along the Mississippi River are over 3 m (10 ft) high.

Drainage Systems of the United States

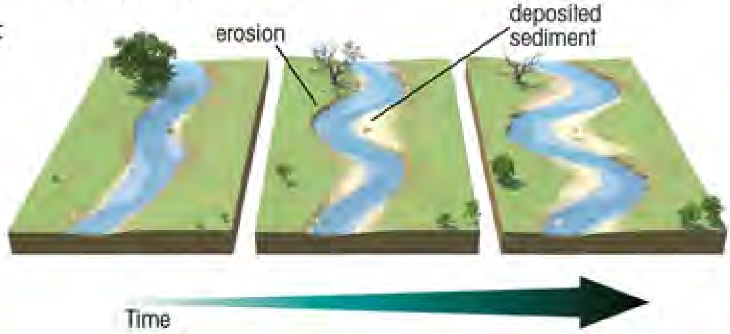
A river on a soft, flat floodplain may develop curves and twists, creating a course that bends like a snake. These winding, looping curves are called **meanders**. Meanders are constantly changing form and position as the river deposits sediment on the inside of each curve and erodes sediment on the outside. The width of a meandering riverbed stays about the same, but the meanders themselves move; thus, the path of the river becomes more twisted over the years.

Sometimes a river takes a shortcut and bypasses a meander; this may occur if the river becomes swollen from heavy rains or springtime runoff. When a meander is bypassed and becomes cut off from the rest of the river, it forms a crescent-shaped body of water known as an **oxbow lake** (because its shape resembles the U-shaped yoke, or bow, of an ox). There are many large oxbow lakes in the Mississippi River's floodplain.

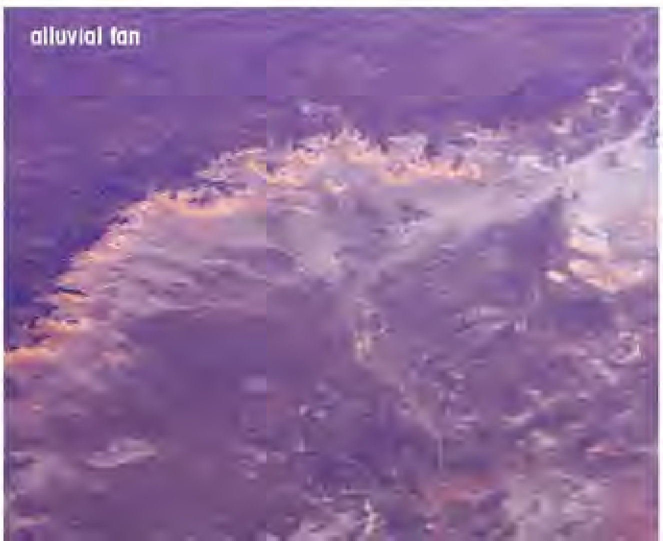
End of the line. When a large river reaches the ocean, it deposits its load of sediment, often forming a **delta**, a fan-shaped or triangular deposit extending from the mouth of the river into the sea. Many deltas grow each year as rivers deposit more sediment; but in some places, ocean currents sweep away sediment as fast as the rivers deliver it. Some deltas are even shrinking due to the rate of erosion.

In deserts, structures similar to deltas form by short-lived streams that result from occasional desert thunderstorms. When a cloudburst occurs, rushing water fills dry desert streambeds and plunges wildly down the mountainsides, carrying loads of rock and sediment. At the bottom of the mountains, the water spreads out, loses its power, and quickly soaks into the sandy ground. The sediments are left on the plain in a delta-like deposit called an **alluvial** [ə·lo͞o′vē·əl] **fan**.

Meander Formation



Oxbow Lake Formation



look at other objects, both on the earth and in the sky.

STEP 7 Use the following procedure to magnify the sun with your telescope. Hold the telescope with the objective lens pointed at the sun. Place a sheet of white paper where you would normally place your eye. Adjust the distance between the piece of paper and the eyepiece to get a good view of the sun. **Caution:** To avoid permanent injury, be sure you do not accidentally look at the sun through either lens while you are performing this observation.

Questions

1. When viewing a distant object through the telescope, does the object appear right side up or upside down?
2. Calculate your telescope's magnification using the equation given in the introduction.
3. When observing the sun through your telescope, were you able to see sunspots?
4. Calculate the magnification of a telescope whose objective has a focal length of 20 cm and whose eyepiece has a focal length of 5 cm.
5. Why are lenses of two different focal lengths needed to make a refracting telescope? Why should the lens with the longer focal length be chosen as the objective? (Hint: Consider how using the shorter-focal-length lens as the objective would affect the magnification.)

Reflecting telescopes. English scientist Sir Isaac Newton built the first **reflecting telescope**. Reflecting telescopes use a large, curved mirror in place of an objective lens; this mirror is called either the *primary mirror* or the *objective mirror*. Because lenses refract (bend) different colors of light at different angles, it is difficult to keep the images they produce sharp. Mirrors, on the other hand, reflect all colors at the same angle, producing a much sharper image. Newton understood that if parallel rays of light fall on a specially curved mirror, the mirror reflects the rays and brings them into focus at a point in front of itself. The image formed by the curved mirror can then be reflected into an eyepiece by a small, flat mirror (the *secondary mirror*), and enlarged by the eyepiece.

Astronomers usually prefer reflecting telescopes because mirrors can be cheaper and much larger than lenses. Generally, making a telescope's objective (whether it is an objective lens or an objective mirror) wider causes the telescope to produce brighter images, allowing astronomers to better view faint objects. A larger objective also increases the *resolution*, or level of detail, of the telescope. Using a more powerful eyepiece magnifies the image more; although high magnification is useful for looking at objects within the solar system and some large, distant objects like nebulae and galaxies, it is usually not very useful for looking at stars.

Dig Deeper

The largest reflecting telescopes can change the shape of their primary mirror to account for distortions caused by gravity, air pressure, and the position of the telescope.

Scientists have made many improvements to reflecting telescopes, resulting in several different types of reflecting telescopes in use today. Although

Newtonian Reflecting Telescope

Keck 1 Reflecting Telescope

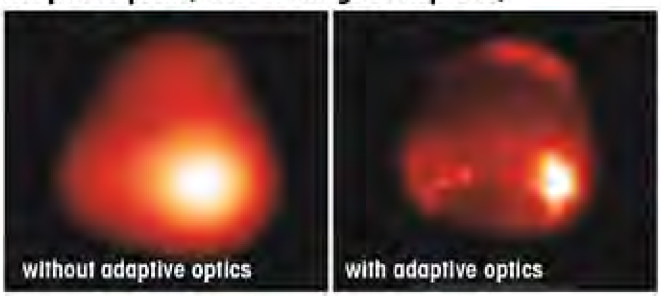
telescopes built to Isaac Newton's design (called *Newtonian telescopes*) are popular among amateur astronomers, professional astronomers often need the advantages provided by newer designs. The largest optical reflecting telescopes in the world have primary mirrors more than 10 m (33 ft) across; several telescopes are planned that will be much larger when built.

Overcoming obstacles. Astronomers probing the heavens with visible light have always contended with several obstacles to their observations. One of these hindrances is the extreme faintness of the light from most distant objects; this obstacle may be overcome by making telescopes bigger, which allows them to gather more light. To increase their ability to detect faint objects, most large telescopes are also equipped with sensitive digital cameras instead of simple eyepieces. These cameras are much more sensitive to dim light than the eye is, revealing faint details that a person looking through the telescope could not see.

Another problem is the earth's atmosphere itself. Air currents in the lower atmosphere, which make the stars appear to twinkle even to the unaided eye, lower a telescope's resolution and can ruin visual images at extreme magnification. Modern technology has helped overcome this obstacle to ground-based astronomy. In one technique, called **adaptive optics,** computer-controlled mirrors that constantly flex and bend to correct for atmospheric distortion are installed between the primary mirror and the camera of a large telescope. By changing their shape many times a second, these mirrors make the images of the stars almost completely free from atmospheric distortion.

A long-established way to avoid atmospheric distortion in optical astronomy is to position a telescope on a mountain, above the thickest part of the atmosphere. In 1990, NASA and the European Space

Adaptive Optics (infrared image of Neptune)



Backyard Scientist

Magnifying the Moon

On a clear night with a full moon, you can experiment with a "reflecting telescope" in your own home. Stand a *cosmetic mirror or shaving mirror* in front of a window facing the moon and aim it at the moon; this mirror will serve as your objective mirror. Stand a *flat mirror* in front of the objective mirror and position it so that you can see the image of the moon reflected from the objective mirror. Look at the reflection in the flat mirror through a *hand lens*—the moon will look brighter. Adjust the positions of the mirrors and hand lens to produce the best image.