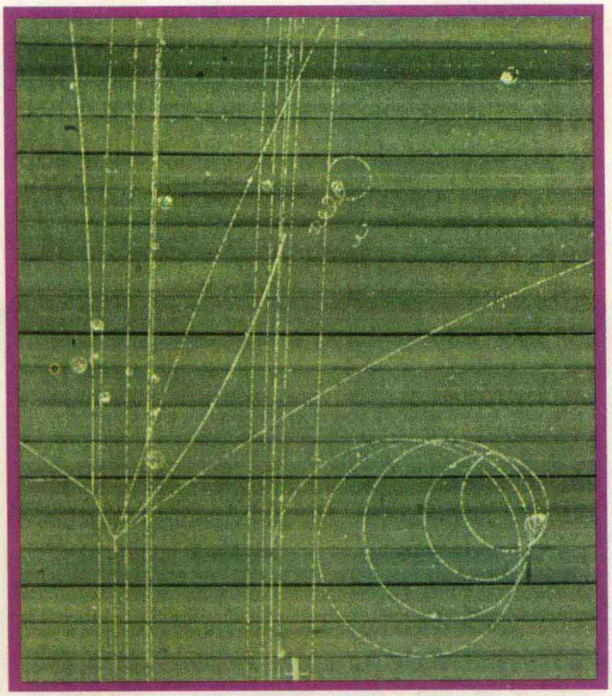
California State Series

TODAY'S BASIC SCIENCE



The Atom and the Earth

An interdisciplinary science program with experiments and observations for the student

California State Series

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John Gabriel Navarra John Edward Garone

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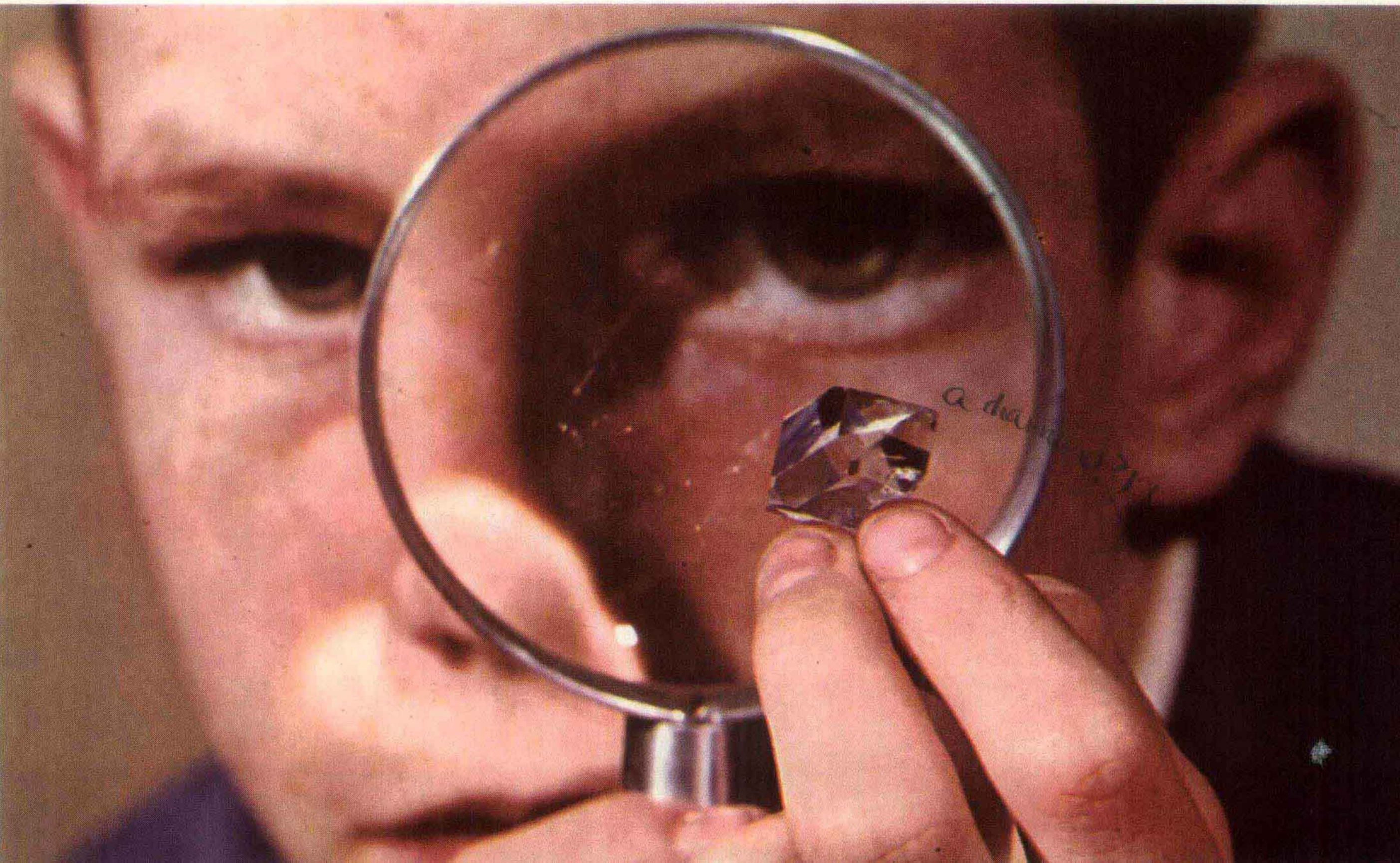

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COVER

The picture on the cover of this book is one of the few color photographs of atomic interactions. The photograph shows the tracks of elementary particles in the 72-inch liquid-hydrogen bubble chamber at the Lawrence Radiation Laboratory, University of California. A giant accelerator called a *bevatron* shoots the high-speed particles into the bubble chamber. The particles then give rise to bubbles in the liquid hydrogen, indicating the presence of protons, electrons, and mesons. The branches and spirals reveal collisions among the particles.

Cover photograph by Jon Brenneis and Lawrence Radiation Laboratory, University of California.

Preface

You will investigate matter and the relationships of matter to energy and life in your study of *Today's Basic Science: The Atom and the Earth*. In your study of matter, you first will explore the concept of *atomicity*, or the idea that the fundamental unit of matter is the atom. The atom, you will see, touches upon all the physical sciences—chemistry, physics, geology, astronomy, and other disciplines.

Many facts and principles will come into focus as you proceed with your study of matter. Such facts and principles are important. They represent one part of science—that part of science which is a body of knowledge. As you acquire knowledge and enlightenment, you will also develop skills. You will learn the techniques of science. Almost instinctively you will begin to ask questions, to probe, to investigate, to make comparisons, to recognize problems, to seek solutions, to interpret, to frame hypotheses, to test, to retest, to verify, and to form conclusions.

A study of the atom and of the physical sciences is an exciting venture. This study leads you into many areas of investigation. You will explore the laws of motion, the making of molecules, the mechanics of waves, the technology of computers, and the processes of photosynthesis. You will discover relationships. You will see, for example, that the exploration of space is, in many respects, an investigation of the earth.

One of the fundamental objectives of this textbook is to develop fully your comprehension of atomicity. Another goal is to represent science as the sharpest tool man has yet devised for acquiring knowledge and for making discoveries. You, too, can experience the excitement and satisfaction which are derived from science and from the achievements of science.

John Gabriel Navarra
John Edward Garone

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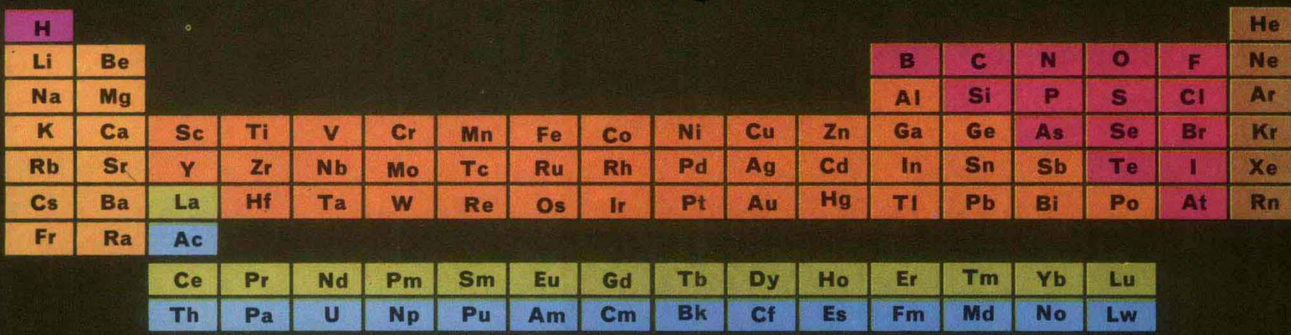
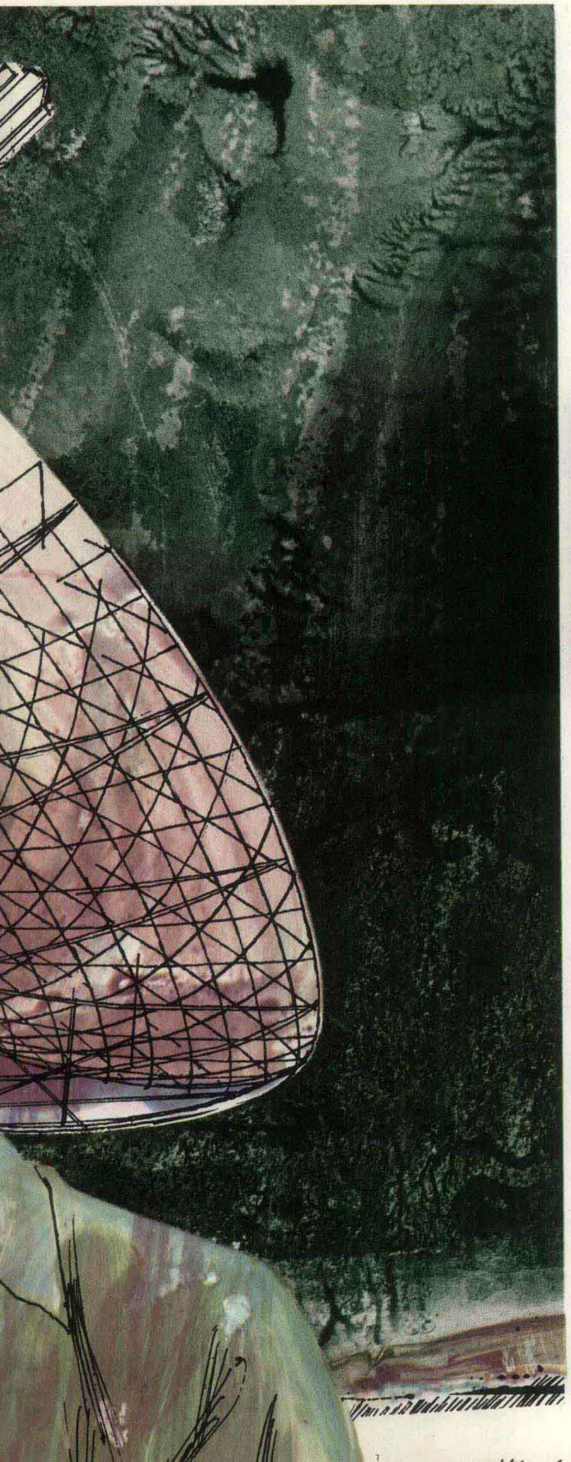
UNIT ONE


H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac
Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lw

INTERACTION, A PROCESS OF SCIENCE



What is *science*? There are several answers to this question. Science is a body of knowledge. It is a set of facts and principles which help to explain our environment. Science is also a method of inquiry—a technique. It is a way of exploring our environment and of finding answers to many perplexing questions.

Science involves many processes. The processes of observation, of experimentation, of investigation, of testing, and of retesting—all these go into the activity known as *science.* The process of interaction is also basic to science and to scientific inquiry. Scientists interact with one another. They observe interacting phenomena—the events among the stars and constellations, for example.

INVESTIGATION 1

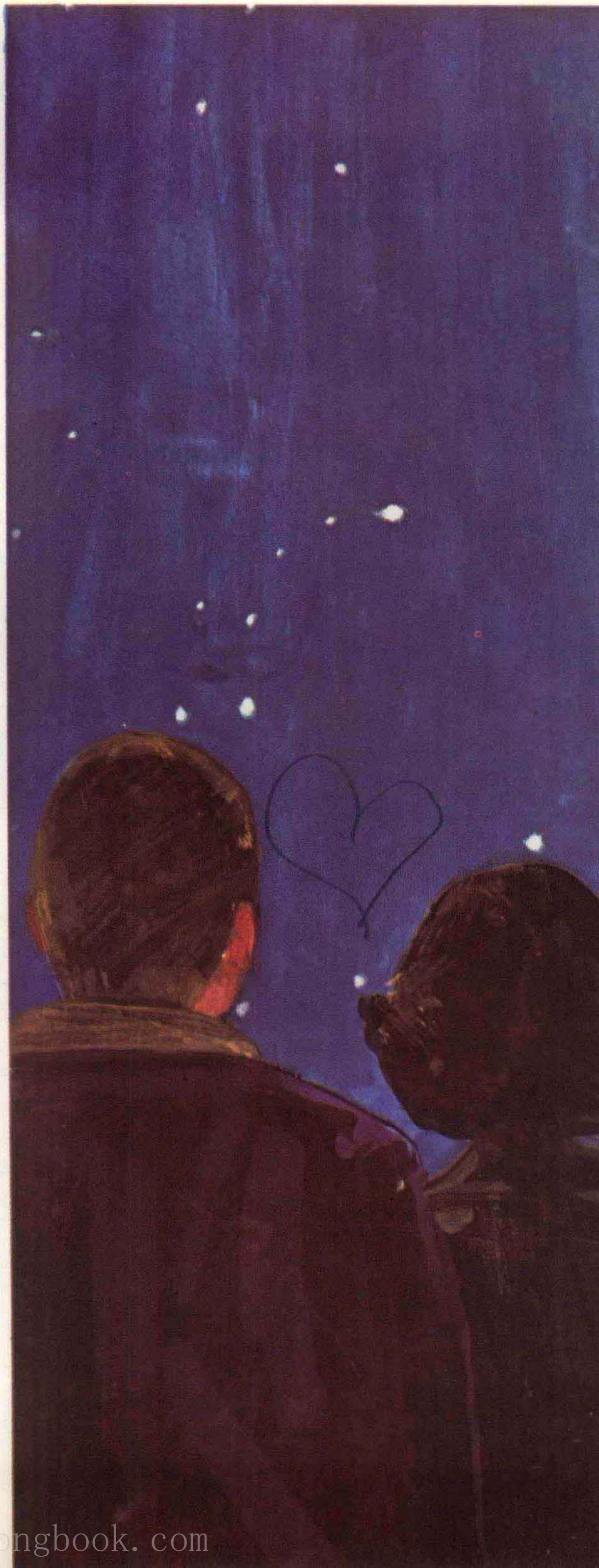
State a problem. Select a problem which you and other members of your class have long been curious about. Then take steps to solve your problem. Find the answers. Strive for originality and thoroughness in the problem-solving methods you employ.

Does a star twinkle? Or does a star only seem to twinkle? This is one problem you might solve. Perhaps you already know the answer. But do you? Can you support your answer with evidence? What proof can you offer?

First, observe a star. Look at it closely. Take a long, hard look. Next, you must undertake some research. Refer to books, journals, and encyclopedias. Then talk to others. Ask (1) an astronomer, (2) an English teacher, (3) your science teacher, (4) a college student, (5) a businessman, (6) a junior-high student, and (7) a kindergarten pupil what each knows about the twinkling of a star.

Be sensitive to the responses of all the people you query. Keep a record. Is there interaction *between you and your consultants? That is, do you respond to each other with an expression of mutual interest? Perhaps you will even detect* interaction *between yourself and a star. Look at it long enough and a star has something to say.*

Does a star twinkle?



Chapter 1

Interacting and Learning

Look into the sky on a clear, cloudless night. Let your eyes roam. Look upward and gaze upon the Milky Way. Do questions cross your mind as you search the heavens and explore this broad band of light? Do you wonder about the universe? Are you curious? What do you know about the Milky Way? What do you see?

Many challenging questions begin to crowd your mind as you take in the vastness and mystery of the nighttime sky. You respond both with emotion and with reason to what you see. On the one hand, you become poetic. At the same time, on the other hand, you ponder the answers to many questions. The poet sets his heart on "one particular beauteous star . . . "[1] The astronomer searches for clues to the expanse and make-up of the universe.

Ask a friend to join you in your exploration of the Milky Way. Compare notes. Do you both respond in precisely the same way to what you see? Talk about your observations. You soon will discover that much can be learned through *interaction*, or through your response to each other and through an exchange of mutual interests.

What is a star? How many stars are in the sky? Why do the stars twinkle? How far away is the most distant star? Do the stars keep shining for ever and ever? Or can a star disappear? Can it explode? Are most stars bigger or smaller than our sun? Are some stars hotter than other stars?

You can readily answer many of these questions. By the time you reached junior high school, you knew almost as much about the stars as did the reputable scientists of ancient times. You have profited from the interactions of many men.

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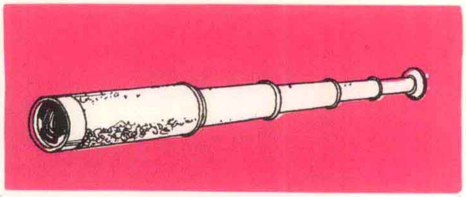
[1]John Keats, "The Fall of Hyperion."



For Interaction and Learning

Interaction *is a process of responding to others and to the things around you.*

The scientist makes discoveries through his interaction with others and with the things around him.

The interactions of many observers have led to discoveries in astronomy and to an understanding of the solar system.

Ptolemy and scientists of the Middle Ages believed the earth was the center of the universe; they believed the sun revolved around the earth.

Copernicus disagreed with Ptolemy; he suggested that the earth revolves around the sun.

Everyone now agrees that the earth and all the other planets revolve around the sun.

PROBLEM

Summarize in a concise list all the things you know about the Milky Way. What is the Milky Way? Is the earth a part of the Milky Way? What are the dimensions of the Milky Way? Make your summary as complete as you can. Then put it aside. Plan on returning to your list of Milky Way facts at the conclusion of this chapter.

The Milky Way *is shown in a flat projection,* right. *The unusual map was drawn by a Swedish artist, Martin Keskula, and his wife. To make the map, the Keskulas drew 7,000 individual stars on photographs of the nighttime sky.*

Interacting Astronomers

Primitive men tried to learn something about the sun, the moon, and the then-known planets. They were drawn to the stars and the planets because they believed these bodies ruled the skies and the earth. The early investigators mixed fact with fancy in their study of the heavens. Superstition clouded their thinking. Yet, these men learned to depend upon the regularities of the heavenly bodies as a measure of time.

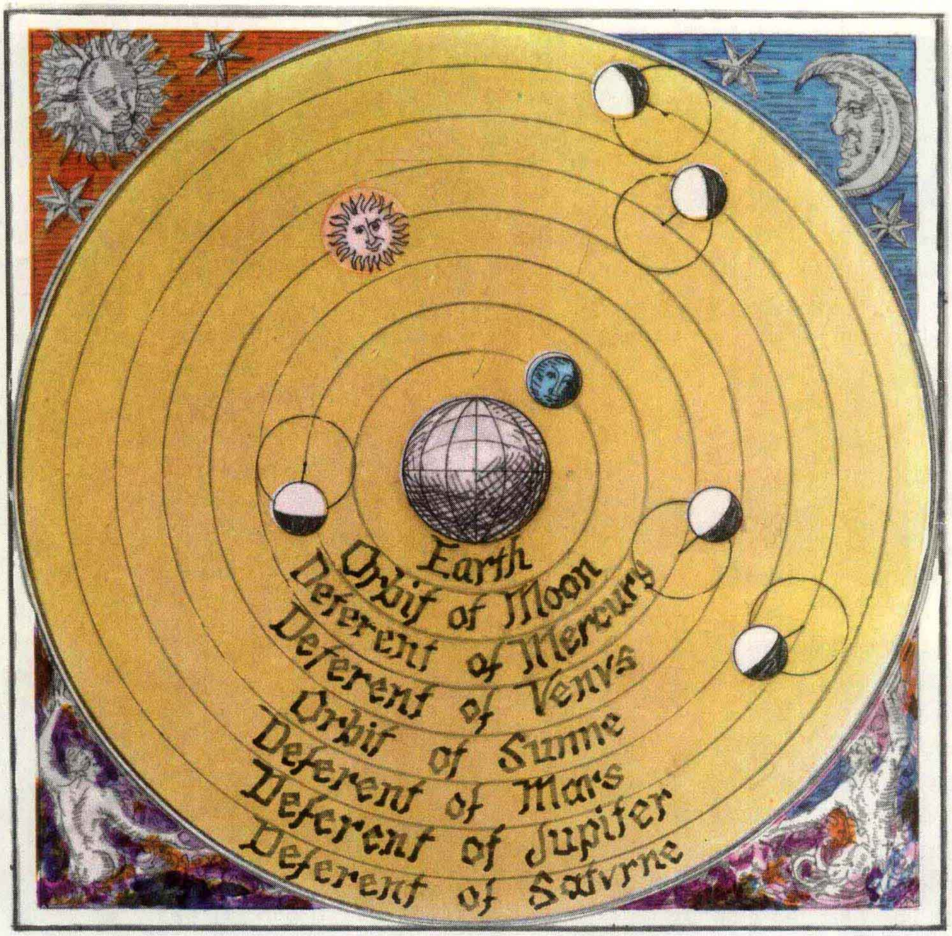
The Greeks, too, mixed myth and superstition with observable phenomena in their exploration of the skies. In spite of many false beliefs, a number of Greek scholars made important discoveries. These wise and perceptive men are regarded as the founders of astronomy. Some of their conclusions are now accepted as established facts. The observations of today's astronomers have verified their findings.

Heraclides (her′ a klī′ dēz), a Greek philosopher of the fourth century B.C., proposed

that the earth rotates, not the dome above it. Democritus (di mok′ rə təs), who lived in the late fifth and fourth centuries B.C., theorized that the misty Milky Way is actually a vast collection of distant stars. Aristarchus (ar′ is tär′ kəs) of Samos, a Greek astronomer of the third century B.C., suggested that the earth and all the other planets revolve around the sun. Two thousand years passed by before people in general accepted this true explanation of the solar system.

PTOLEMY

A man who was mostly wrong in his theories about the solar system ranks among the greatest astronomers of ancient times. This man was Ptolemy (tol′ ə mi), an Egyptian, who wrote of his astronomical theories in about A.D. 150. He described his observations in an impressive 13-volume work entitled *Mathematike Syntaxis*, better known as the *Almagest* (its Arabic title).



Astronomers refer to Ptolemy's theories of the universe and of planetary motion as the *Ptolemaic* (tol′ ə mā′ ik) *system*. Although wholly discredited, the *Ptolemaic system* is regarded as one of the great ideas in the history of science. For nearly fifteen centuries, everyone accepted Ptolemy's description of the solar system. In fact, a denial of the *Ptolemaic system* was looked upon as heresy.

The *Ptolemaic system* placed the earth in the center of the universe. According to Ptolemy, the sun and all the planets revolved around the earth. Each planet revolved in a small *epicycle*, or circle. As it turned within its epicycle, the planet also traveled around the earth in a circular path known as a *deferent* (def′ ər ənt). The center of each deferent was near the center of the earth. A drawing of the *Ptolemaic* system appears on page 14.

As Ptolemy saw things, the earth remained stationary. This motionless earth, according to his theory, was the center of the universe. The whole idea appealed to the people of Ptolemy's time. After all, it seemed logical to assume that the earth was the center of things—the earth with its human population. Even the sun, these people insisted, revolved around the earth.

There is no denying that the *Ptolemaic system* represented some impressive astronomical reasoning. In devising the system, Ptolemy tried to answer many questions about planetary motion. We know now that the earth and all the other planets revolve around the sun, but Ptolemy nevertheless supported his theory with mathematical explanations of how the planets varied their speeds as they circled their epicycles.

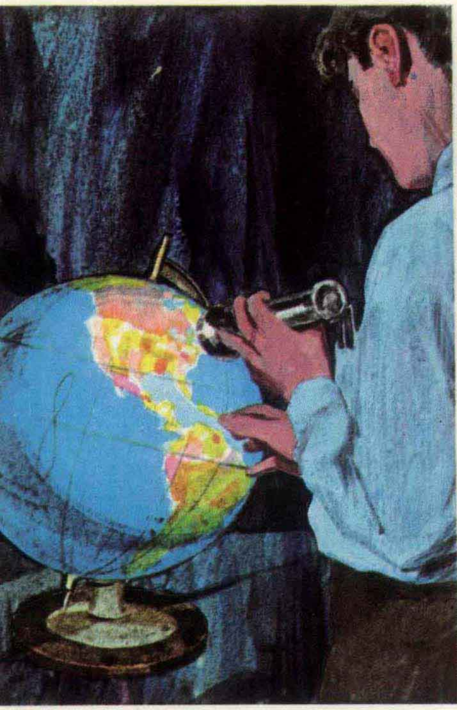
COPERNICUS

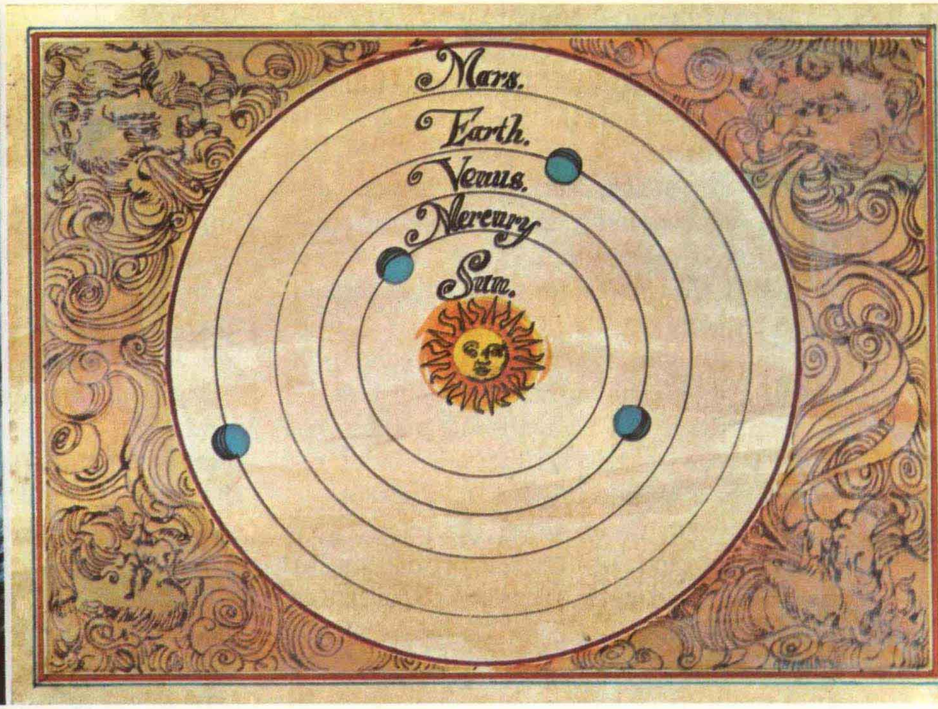
Scientists and laymen alike went along with the *Ptolemaic system* for fifteen hundred years. Anyone who challenged the notion of an earth-centered universe became an unpopular figure. Then, in 1543, the year of his death, Nicolaus Copernicus (1473-1543), published a new theory. Copernicus came forth with the idea that the earth and all the other planets revolve around the sun.

For the most part, the *Copernican system* is now accepted as a true explanation of the solar system. Everyone understands that the planets revolve around the sun. The sun, not the earth, is the center of the solar system. Moreover, we all agree that the earth rotates on its axis. This concept of the earth's rotation was a part of Copernicus's theory.

In devising his system, Copernicus disregarded the apparent motions of the heavenly bodies. That is, he recognized that the motions of the sun and planets are not actually as they seem to be from earth. Even in this day we must admit that the sun does seem to move across the earth from east to west. Yet, like Copernicus, we recognize that the sun only seems to sweep across the earth. Actually, it does not.

The rotation of the earth makes it appear that the sun passes overhead in an east-to-west direction. You can easily demonstrate this rotation with a flashlight and a globe. Let the flashlight be the sun. Shine the flashlight beam onto the globe. Rotate the globe. Note how parts of the "earth" pass from "sunlight" into the nighttime "shadow." It is the globe that moves, not the light itself.





Standing on earth, we have no sensation of its movement. Yet, the earth moves through space. It revolves around the sun once each year. At the same time, it rotates once on its axis about every 24 hours. In addition, the sun, the earth, and all the other planets are speeding through space toward a star called *Vega* (vē′ gə). The sun and the planets move along together at a speed of 66,600 mph.

Copernicus put the earth and the planets on the right track when he rejected the *Ptolemaic system*. Yet, in working out his own system, Copernicus borrowed many ideas from Ptolemy. For one thing, Ptolemy was not altogether wrong in some of his mathematical calculations. To justify his observations, Copernicus also proposed that the planets moved in separate epicycles, a theory which scientists now can see is wrong.

Thus, we have evidence of much interaction between Ptolemy and Copernicus. The two men lived in different eras, but the ideas of one remained alive through the centuries and were factors to be considered in the thinking of the other. Such is the way of science and of scientists. Every investigation involves interaction between the various researchers and also, in a sense, between their various ideas.

The *Copernican system* laid the ground rules for further interaction in the study of astronomy. Galileo Galilei (1564-1642) used