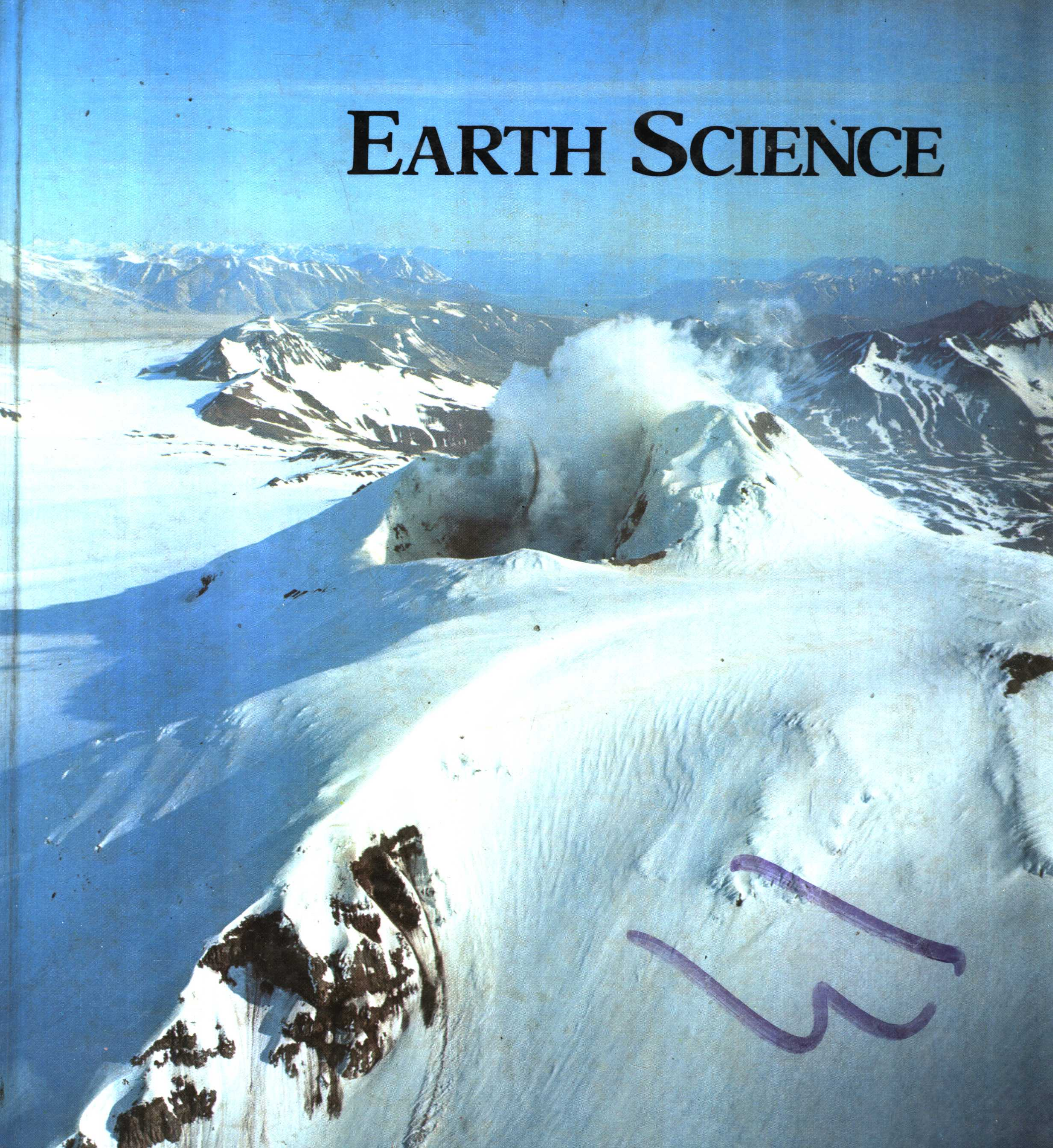
EARTH SCIENCE



EARTH SCIENCE

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with the editorial assistance of

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Preface

In this edition of EARTH SCIENCE every effort has been made to simplify the language of the text while maintaining the treatment of the subject at the same high level as in the preceding editions. Emphasis on scientific inquiry has been continued and expanded. Students begin with inquiries on their own from every chapter. Then students are introduced to the questions and problems that challenge the earth scientist. Throughout the text students devise and conduct simple inquiries of their own into problems of the earth sciences.

In those sections of EARTH SCIENCE that deal with origins and evolution, scientific data have been used to present this material as theory rather than fact. The information presented allows for the widest possible interpretation that can be applied to any set of values, either religious or scientific. Every effort has been made to present this material in a nondogmatic manner.

New Text Materials

This edition is primarily an updated version of the prior edition. Parts have been rewritten to reflect the latest scientific discoveries. Chapter 20, *The Sun and the Solar System*, reports the recent findings of Pioneer 11, Voyager 1, and Voyager 2. More current photographs of the planets have been added.

Learning Aids

In addition to the features just described, this edition retains many of the learning tools teachers have found so helpful in previous editions. These include:

1. ***Illustrative Materials.*** Full-color and black-and-white photographs, including many color photos of rocks and minerals, two-color line drawings, and tables and charts are used to introduce, reinforce, and extend concepts. New line drawings and carefully selected new photographs, mostly in full color, have been added to maintain the high standard of illustration throughout the text.

2. ***Topic Questions.*** Numbered Topic Questions at the end of each chapter direct students to the main ideas covered in the same-numbered topic within the chapter.

3. ***General Questions.*** These questions at the end of the chapter call for student application of concepts to new problems. Some questions require students to tie together the main ideas of several topics.

4. ***Student Activities.*** These activities at the end of the chapter suggest practical investigations and projects related to the work of the chapter.

5. ***Topographic Sheets.*** Suggestions and references for topographic maps pertinent to chapter content are listed at the end of the chapter.

6. ***Vocabulary and Pronunciation Guides.*** Key vocabulary words are printed in bold-face type within the text. The phonetic pronunciation of difficult or unfamiliar words is provided within the text following the first appearance of the word.

7. ***Appendix.*** At the end of the book is an appendix that includes a chapter on topographic maps, measurement tables, a table of the chemical elements, a simple key to the identification of minerals, and a table listing the properties of the common minerals.

8. ***Glossary and Index.*** At the end of the book there is an extensive glossary and an exhaustive index.

Components

TEACHER'S EDITION helps the teacher manage an earth science program that has both variety and appropriateness for different classrooms. A three-track Outline of Topics covered in the basic text shows how topics may be assigned for students of various ability levels. The Guide is organized by lessons, and the topics to be covered in each lesson are indicated; concepts and suggestions for each lesson are provided. Answers to all the General Questions at the end of the chapter are included. The TEACHER'S EDITION also includes sources of visual aids, specific suggestions for films and film-strips, a list of supply houses and sources of materials, and a bibliography.

Annotated Student Text Pages. This feature helps the teacher reinforce major earth science concepts, provides additional information, and suggests additional activities for the student. Over-printed references to experiments from the ACTIVITIES book are given at appropriate places in the text.

ACTIVITIES IN EARTH SCIENCE is a laboratory manual providing "hands-on" learning experiences. It contains a variety of investigations for classroom, laboratory, and the field. Detailed instructions enable students to work on their own or in small groups. The Activities book may be used to supplement the basic earth science program, or it may be used alone to build concepts and process skills in a laboratory-oriented program. An annotated Teacher's Edition is available.

TESTS FOR EARTH SCIENCE is a self-scoring set of chapter tests on spirit duplicating masters. Each chapter of the basic text is covered in a test, and answers are provided on the front of each master in nonreproducing form.

Acknowledgments

The authors wish to acknowledge the assistance given by a number of people at various stages in the evolution of this edition. Critical reviews of units in their areas of specialization were made by Professor Maurice Rosalsky of the Department of Geology, Professor Richard Rommer of the Department of Meteorology and Oceanography, and Dr. Robert Wolf, Chairman of the Department of Physics, all at the City College of New York. Dr. Donald Fisher provided a critical reading of the Earth History Unit. Last, but not least, the authors wish to thank the many correspondents, both teachers and pupils, whose helpful suggestions with respect to previous editions have resulted in many subtle refinements in the language and illustrations of the text.

S.N.N., D.B.S.

unit one

Since people have been in space, we have been able to see photographs of the earth as a whole, as shown on the page opposite. Actually, this photo shows only one quarter of the earth. The far side is not seen, of course. Why can't you see all of the near side? What does this tell you about the position of the sun with respect to the earth when the picture was taken from Apollo 10?

Apollo 10 was one of the United States missions to the moon.The part of the earth that can be seen in this photograph includes Europe, Asia, and parts of Africa. These large land masses appear in the photograph almost as a single giant continent. The continents you can't see are separated from these by many kilometers of ocean. It would be easy to suppose that Europe, Asia, and Africa are joined underwater as one continent, and that the other continents have always been separate. Scientists now believe, however, that all the continents and parts of the continents are riding on separate chunks of the earth's crust. The African "chunk," or plate, is separate from the plate that includes Europe and part of Asia. These plates are moving with respect to one another.

It is believed that, at one time in the distant past, the plates containing the continents had moved so that they were all together. All the land was in one place and the rest of the earth was a vast ocean.

Here you see the earth as a ball floating in space, with no neighbors nearer than the moon. Its crust is composed of rocks and minerals, much of it covered by oceans. The earth's atmosphere is filled with clouds of water vapor. All of this, and more, forms the subject matter of earth science.

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Structure of a Dynamic Earth

1

HOW DO YOU KNOW THAT... ?

The sun and other stars are very hot. The earth's interior is also hot. Where did this heat come from? Some sources are suggested in the following investigations.

1. Blow up a balloon. Let the air escape against the back of your hand from only a couple of centimeters away. Is the air hotter or colder than the surrounding air? What caused the difference in temperature?

In this case the change in temperature is caused by expansion of the gas. What do you think will happen if you compress a gas? Try it. Take a bicycle pump and quickly pump up a bicycle tire. Now feel the tire and the valve. Was your prediction correct?

2. Hammer a large nail into a board quickly. When the nail is almost in, stop and feel the nail and the face of the hammer. Is there a temperature change? If so, this change was caused by hitting, or impact.

The Origin of the Earth

Origin of the Solar System

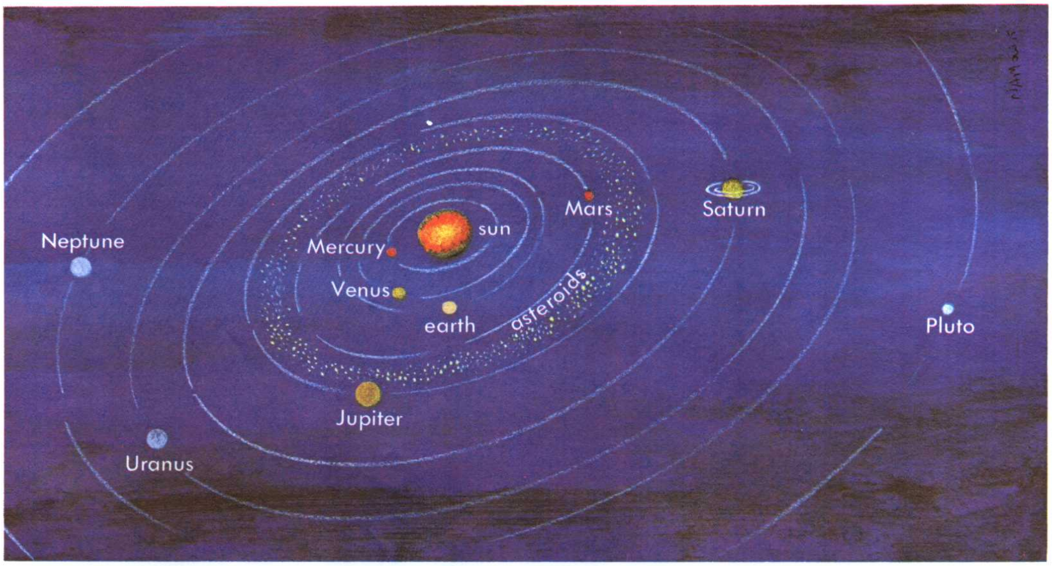
1. What Earth Science Is

Earth science is the study of the earth. It includes *geology,* which is the study of rocks and land, *oceanography,* which is the study of the oceans, and *meteorology* and *climatology,* the study of the atmosphere.

Earth science is also interested in our neighbors in space. So it also includes the science of *astronomy.* Where shall we begin our earth science—land, oceans, atmosphere, sky? Perhaps a good place is where the earth begins—the origin of the earth itself.

Of course, the earth is only one member of a family of planets belonging to the sun. This family is the *solar system.* All of the planets in the solar system probably had their origin at the same time.

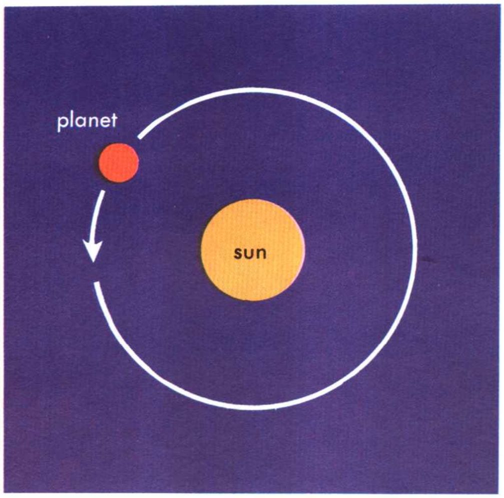
We picture our solar system this way.



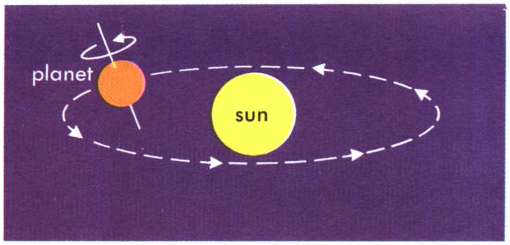
2. Facts about the Solar System

Many explanations, or *hypotheses,* have been proposed for the origin of the solar system. All of them have had to consider these facts:

1. All of the planets *revolve* around the sun in the same direction (counterclockwise as viewed from above our North Pole).
2. The paths, or *orbits,* of the planets around the sun are all nearly circular.



All planets revolve around the sun in long paths.

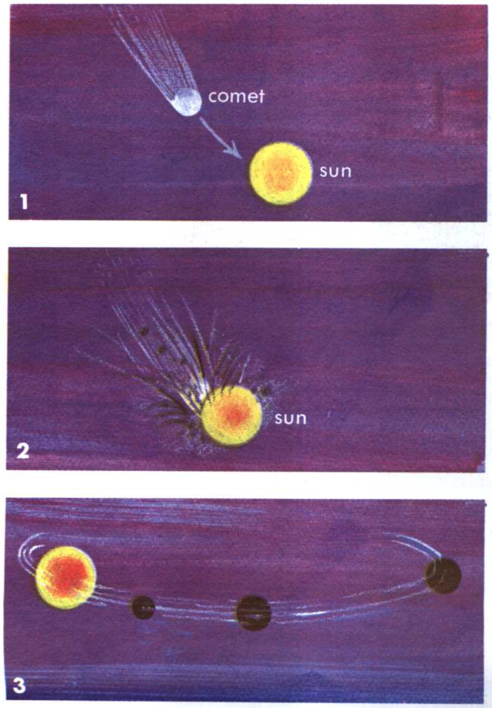


All planets rotate around an imaginary line through their centers.

3. The orbits of the planets are all in nearly the same flat surface, or *plane.*
4. The sun turns on its axis (*rotates*) in almost the same plane as the planets, and in the same direction as they revolve.
5. Most of the planets rotate in the same direction as the sun.
6. Seven planets have moons. Most of these revolve around the planets in the same direction as the planets revolve around the sun.
7. The sun's rate of rotation is slower than expected by scientists.

Let us see how a few famous hypotheses have tried to explain these observed facts.

Encounter Hypotheses 3.



Most hypotheses of the solar system origin fall into two groups: encounter hypotheses and nebular hypotheses.

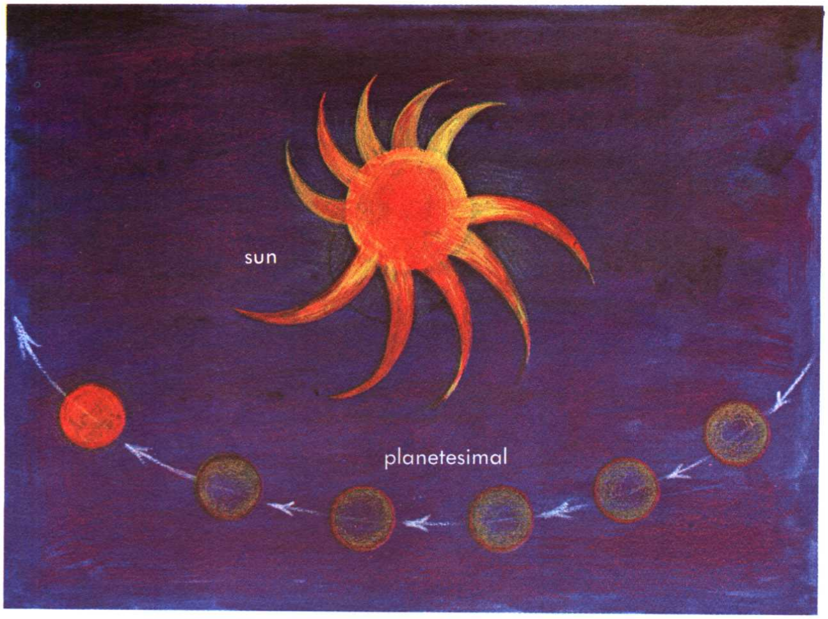
All of the **encounter hypotheses** state that our solar system began nearly five billion years ago, with our sun already in existence. Let us imagine back to that time; the sun is just an ordinary star whirling through space. Then an extraordinary event takes place. Another heavenly object—usually a star—passes very close to the sun.

The first scientist to suggest an encounter hypothesis was Count Buffon of France in 1749. In Buffon's version, the sun's encounter is not with a star. Instead, a great comet collides with the sun!

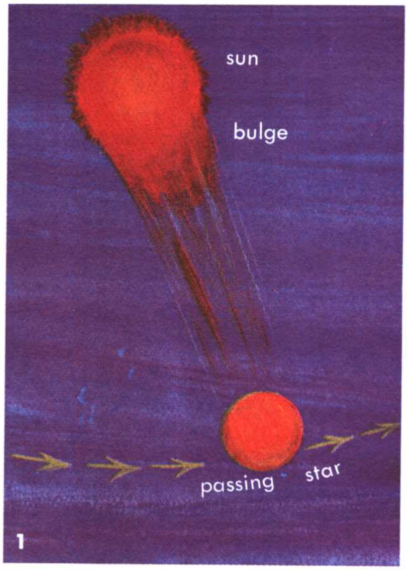
The collision throws many great streams of gas from the sun. These streams all move in the same direction around the sun. After millions of years they shrink into ball-shaped bodies. The largest streams become *planets.* Smaller streams become moons, or *satellites,* of the planets. Still other streams fail to shrink and remain as *comets.*

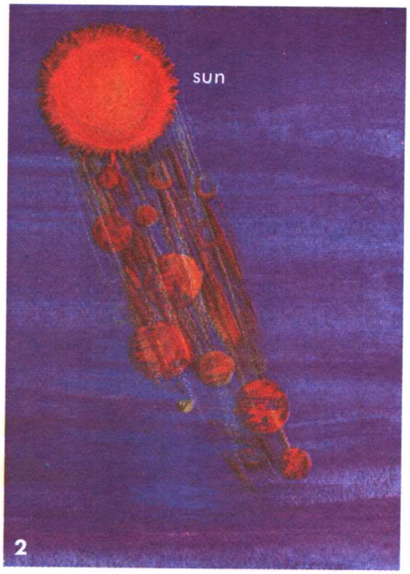
In 1895 the American scientists Chamberlin and Moulton proposed their *planetesimal hypothesis.* This hypothesis avoids a collision

Buffon thought that a comet and the sun collided, throwing out streams of gas from the sun.



Chamberlin and Moulton suggested that a passing star pulled gas from the sun. The gas then shrank into planetesimals.





Jeans and Jeffrey proposed a tidal bulge that was caused by the sun's encounter with another star. The bulge formed into planets.

by using the force of gravity to pull the planets from the sun. Gravity pulls stars together just as it pulls a thrown stone and the earth together.

There is an encounter between the sun and another star, and great quantities of gas flow from the sun into space. The other star's gravitational attraction pulls gas from the sun. The gas shrinks into cold, solid rocklike masses called *planetesimals.* These "grow" together by gravitational attraction and collisions to form the planets and their moons.

Still another hypothesis was the *tidal hypothesis* proposed by the Englishmen Jeans and Jeffrey in 1917. In this explanation, the encounter between the sun and another star is so close that gravitational attraction causes a great tidal bulge in the sun. This bulge splits off and breaks up to form the planets.

What are the weaknesses of encounter hypotheses?

First, the close meeting of two stars (that such hypotheses require) is extremely unlikely.

Second, if planets were formed after stars encountered each other, they should be much closer to the sun than they are.

Third, some of the hypotheses fail to explain why the sun rotates so slowly.

Finally, they have difficulty accounting for the moons of the planets.

Nebular Hypotheses 4.

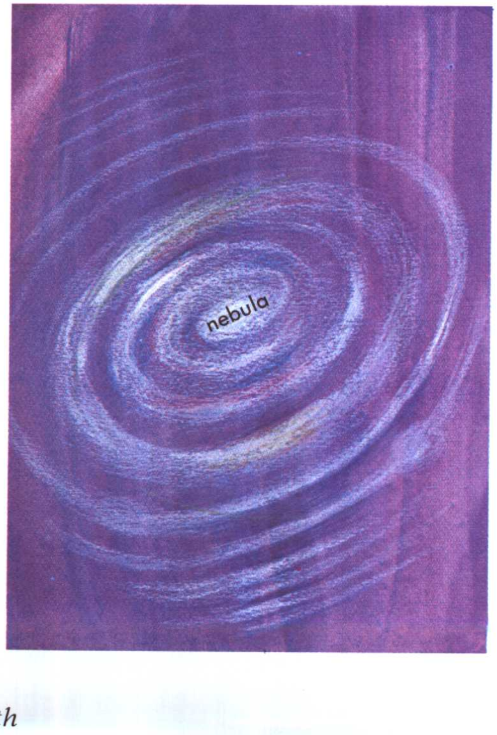
Nebular hypotheses begin with the sun not yet in existence. A huge cloud of gas, much larger than the entire solar system today, rotates slowly in space. Millions of years pass. The great cloud, or *nebula,* cools and shrinks. The shrinking makes it spin faster. This happens for the same reason that spinning skaters spin faster when they fold their arms. The increased speed causes the nebula to throw off a ring, then another, until nine rings form, one inside the other.

Meanwhile the cloud at the center of the rings has shrunk greatly. But shrinking causes compression, and compression causes heating. (Feel the valve when you pump up a tire!) The cloud at the center of the ring becomes fiery hot, "burning" in the same way as a hydrogen bomb burns, but with enough hydrogen fuel to last it for many billions of years. It has become the star we call the sun.

While this takes place, the nine rings split open and shrink into planets and their moons. Sun, planets, and moons are all spinning in the same direction as the nebula from which they were formed.

A nebular hypothesis was first suggested by the German scientist Kant in 1755. Kant's idea was slightly changed by the Frenchman Laplace in 1796.

Critics of the nebular hypothesis have pointed out two major weaknesses in it. First, the "rings" could not have contained enough matter to condense into planets. Second, it too fails to explain why the sun rotates so slowly.



The nebular hypothesis of Laplace was a popular theory for many years. As a great cloud spins, it throws off nine rings that form the planets.

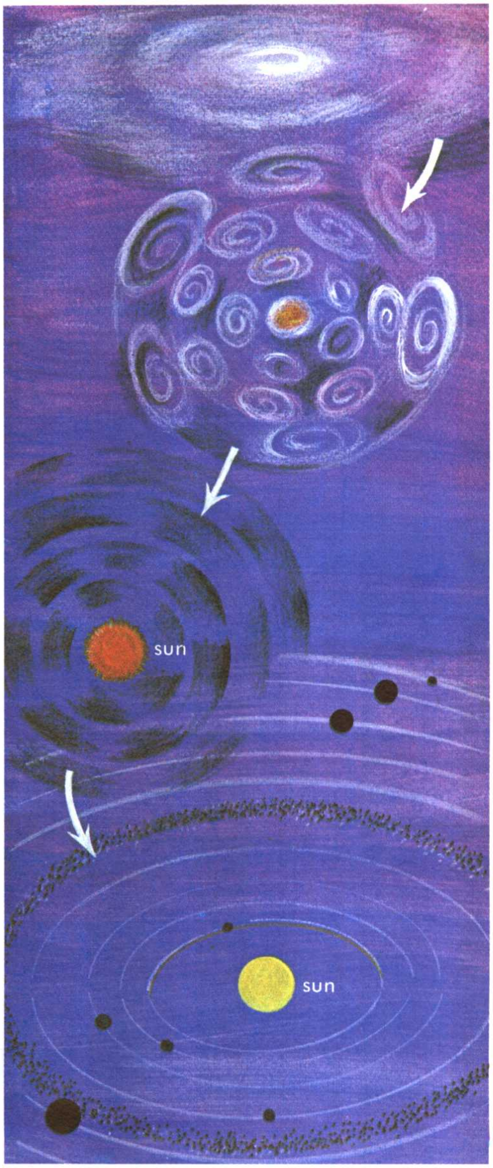
5. Protoplanet Hypothesis

Even today we have no complete explanation of the origin of the solar system. The hypothesis most in favor now is the **protoplanet hypothesis.** It was first proposed about the year 1944 by the German astronomer von Weizsacker.

Like the nebular hypothesis, the protoplanet hypothesis begins with a great cloud of gas and dust. The cloud shrinks under the pull of its own gravitation. Most of its material gathers around its center, becoming hot enough by compression to form the sun. Unlike the nebular hypothesis, however, no separate rings are formed. About 10 percent of the matter in the cloud forms a single disk around the sun. The disk rotates slowly with the sun. Friction within the disk causes most of its material to collect in several huge whirlpool-like *eddies.* These shrink into more compact masses called *protoplanets,* and later into planets and moons. Some "uncollected" materials still remain as comets, meteors, and planetoids.

How does this modern hypothesis overcome the objections to the nebular hypothesis? First, it replaces the unlikely rings with more likely eddies. Second, it suggests an explanation of the sun's slow rotation.

Why do modern hypotheses favor a nebular origin over a star-encounter origin? The answer lies in the low probability of stars' meeting. Although there are millions of stars, they are very far apart. Star encounters are the rarest of happenings at best.



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1 The protoplanet hypothesis is favored today. It, too, begins with a cloud of dust and gas.

2 Gravity causes the cloud to shrink. As it does, eddies form in the cloud.

3 The eddies also shrink, forming the masses that become the planets.

4 Finally the protoplanets change into the planets and moons we know today.

How the Oceans, Atmosphere, and Rocks Are Formed

Origin of the Oceans 6.

Scientists now agree that when the earth first formed, it had neither oceans nor atmosphere. But as the protoplanet Earth changed to the planet Earth, it grew hotter and hotter. There were three sources of heat: compression, radioactive minerals, and bombardment by showers of meteors. Radioactive minerals are natural substances that give off energy, which becomes heat. Meteors produce heat both by friction and by impact. (Feel a nail that has been hit hard several times with a hammer!)

When the earth became hot enough, volcanoes erupted, bringing hot liquid rock (*lava*) and hot gases to the surface. The gases contained vast amounts of steam, which turned into the water that slowly filled the oceans. This was fresh water. The salt we now find in ocean waters was carried into them by rivers over billions of years. The rivers dissolved the salt from the rocks over which they flowed.

Origin of the Atmosphere 7.

The atmosphere that surrounds the earth today includes about 78% nitrogen and 21% oxygen. These gases are *free;* they are not combined with other elements. The remaining 1% is mostly the gases argon, carbon dioxide, and helium. (Water vapor is in the atmosphere, too; but it varies in amount with weather and climate.)

This present mixture is very different from what scientists think the earth's original atmosphere must have been. They believe that the original atmosphere came from volcanoes and was like the mixture of gases that now erupts from volcanoes. This mixture usually is more than half water vapor, with large amounts of carbon dioxide and sulfur gases. But it contains *no free oxygen!*

Almost all forms of life on the earth today need free oxygen. Where, then, did it come from? Scientists think the atmosphere's first free oxygen came from the breakup of water molecules by sunlight in the upper atmosphere. Water is a particular combination of hydrogen and oxygen. Then as simple green plants came into existence, they added more and more free oxygen to the atmosphere by *photosynthesis.* In this process, green plants manufacture sugars and starches from carbon dioxide and water in the presence of sunlight. But more than half of the oxygen in the carbon dioxide and water is left over. This is released into the atmosphere as free oxygen.