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ABSTRACT

This publication contains an extensive introduction for teachers covering such topics as questioning, reading in the science program, evaluation, and audiovisual materials. The book itself is a teacher's guide and is based on the concept that learning is best facilitated by providing meaningful problems which the learner is able to solve. Topics covered include light and the camera, magnets, the stars, molecules and atoms, air, plants and tools scientists use. A two-level bibliography (for pupils, for teachers) is also included. (BB)

SCIENCE

Grade 6

BUREAU OF CURRICULUM DEVELOPMENT
BOARD OF EDUCATION • CITY OF NEW YORK

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CURRICULUM BULLETIN • SERIES 1971-72 • No. 6

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Grade 6

BUREAU OF CURRICULUM DEVELOPMENT
BOARD OF EDUCATION • CITY OF NEW YORK

FOREWORD

In the past decade science instruction has become an integral part of the elementary school program, from the prekindergarten through the sixth grade. Science has a unique role in the curriculum because it offers opportunities for all children to explore and to discover the what, the how, and the why of the world around them.

The science program is based on the concept that learning occurs when the learner attempts to solve a problem which he finds meaningful. *Science: Grade 6* provides the teacher with specific materials and suggestions for organizing effective learning experiences in the science area in harmony with this concept. Both science knowledge and science processes are stressed. Significant findings from national projects have been incorporated. Among the new features which merit special attention are the evaluative activities which follow each of the major topics.

In behalf of the school system I wish to express my appreciation to the Bureau of Curriculum Development, the Bureau of Science, superintendents, directors, elementary science coordinators, and to the hundreds of teachers and supervisors who have made this publication possible by tryouts in the classroom, by designing of materials, and by their participation in the preparation of this handbook.

SEELIG LESTER
Deputy Superintendent of Schools

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Harry Milgrom, Director of Science (Acting), organized the Elementary Science Revision Committee and directed it in redesigning the science program.

Julius Schwartz, curriculum writer of the Bureau of Curriculum Development, coordinated the research and writing for *Science: Grade 6*. In this work he was assisted by Anna M. Rosenblum.

The following, members of the Revision Committee, participated in the writing, testing, and evaluation of the materials: George Barr, Samuel Belf, Rose Blaustein, Lillian Feldman, Mary Graeber, William Plummer, Robert Rice, Anna M. Rosenblum, Joan Rosner, Eli Slotkin, and Bernard Spar.

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of the seven handbooks in the original K-6 science series which has served as the basis for the current revision program.

This publication was designed and produced by the Bureau of Curriculum Development. Edythe Kahn, Editor, supervised printing production; Eleanor A. Shea edited the manuscript; Morris Kelvin prepared the page layout; and Jan Margo drew the illustrations.

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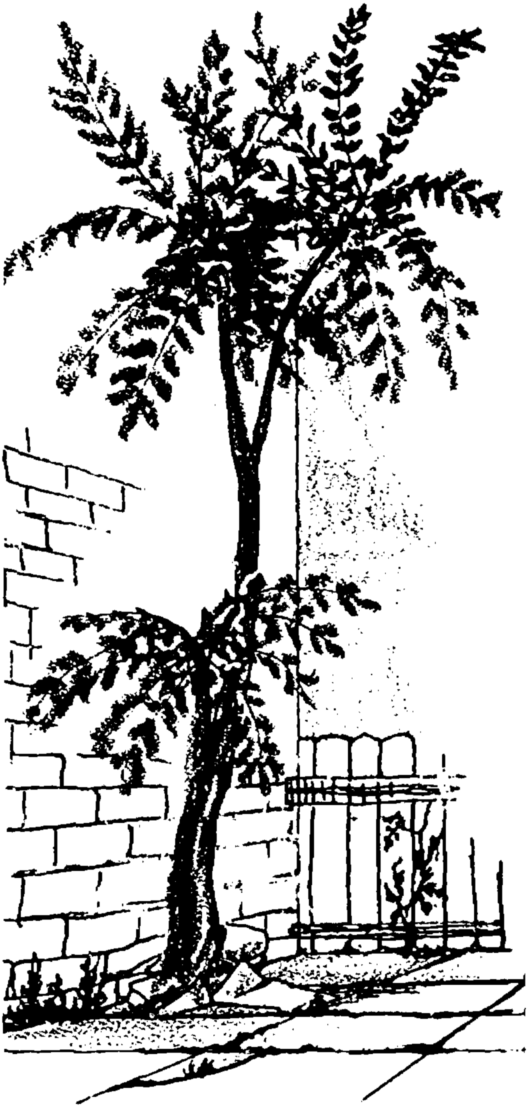


Introduction

MEETING THE NEEDS OF ALL CHILDREN

Science meets the needs of all children since it offers them endless opportunities to explore, to manipulate, and to discover, as they try to find the what, the how, and the why of the world around them. The science program is designed to provide a variety of experiences in the form of trips, experiments, demonstrations, and projects which will appeal to children of varying backgrounds, interests, and capabilities.

The topic *Moving in Space,* for example, begins with the question "What spaceships have you seen blasting off?" This is an invitation to the children to pool their experiences and knowledge—and to ask their own questions—with respect to the launching of space vehicles. The topic may stimulate reports, based on magazine and newspaper articles, books, and television programs. Children may wish to make models, charts, and drawings depicting current space missions.

As the study proceeds, the children build a "jet-sled" with which they demonstrate how a spaceship is lifted off its pad. Other demonstrations and experiments help them understand how gravity affects space flight, how man-made satellites are placed in orbit to travel around the earth, and what keeps them in orbit. The children evaluate the facts and figures of one Apollo spaceship to determine why a space rocket uses several stages. They construct and experiment with a working model to demonstrate how a spaceship escapes from earth and reaches the moon.

Science lessons come in many "sizes" and "shapes." Characteristically, children may be experimenting, constructing, discussing, reading, observing, making drawings, making measurements, making exhibits, taking care of plants and animals. Science lessons may take the form of a planned trip in or around the school building, to the school garden, in the neighborhood, or to a nearby park. A science lesson may be the spontaneous reporting by children of what the windstorm did the previous night. A science experience may last two minutes, five minutes, an hour, or more. It may be part of an interrelated series of experiences and activities, or it may stand uniquely by itself.

There are many roads to science learning, and there are many settings for science teaching. The developmental class lesson, led by the teacher, is only one of the forms that a lesson may take. On different occasions, children may work in small groups or by themselves. Since children learn at different rates and in different ways, there must be many opportunities for individual work. Children need time to think, time to work things out for themselves without pressure from their classmates or teacher. Not all children will be working in science at the same time.

Using This Handbook to Meet the Needs of All Children

In Approaches and Learnings for the Child, there are presented for each topic, the significant concepts which all children should learn. Following these are suggested problems. For example, in "Molecules and Atoms," Topic A, Everything Is Made of Molecules, is developed through study of such problems as these:

1. How can we break a lump of sugar into its tiniest pieces?
2. How many molecules are there in a spoonful of sugar?
3. What is the smallest bit of water you can get?
4. How can we collect water molecules from the air?
5. Are there spaces between molecules?
6. Can you smell molecules?
7. How do molecules move around?
8. What holds things together?
9. Can we see molecules move?
10. Can we make molecules move faster?
11. What happens to the size of substances when they are heated?

For each topic the teacher *will use those problems that best serve the needs and interests of group.* The problems should also be selected to develop adequately the basic concepts stated in the introduction to the topic. The teacher should feel free to extend the investigation of the topic along lines suggested by the children.

Following each problem in this handbook is a list of concepts which the children may be expected to learn. *It is important that the concepts be formulated by the children on the basis of their experiences and be* *expressed in their own words. It is not intended that all children or all classes arrive at all of these understandings, or be limited solely to these.*

In summary: When science is approached as exploration, each child is invited to make his own contribution and to share in all learnings.

SCIENCE AS PROCESS AND AS KNOWLEDGE

The material in this handbook is designed to combine the two components of science, process and knowledge. For example, when children develop and carry out a plan to determine how to make an electromagnet stronger, they engage in the *processes* of science discovery. When they arrive at the generalization that an electromagnet may be made stronger by winding more turns of wire around an iron core, they have acquired science *knowledge*.

The understandings listed at the end of each problem in this handbook and the broader concepts found in the introduction to each topic represent *knowledge* that should flow from the children's investigations. Interwoven in the development of each problem and implicit in the question which triggers each problem is the *process*.

Following are some of the processes in science investigations. The list given here is not intended to suggest the order in which the investigation is to proceed. Nor is it essential that all processes be included in any one investigation. *It is necessary to keep in mind that while children are discovering, they should be finding out something which they want to know and need to know.*

1. *Asking Questions.* This handbook is designed to encourage the asking of questions. The posing of a question is an invitation to children to engage in a scientific enterprise. Of course, the most significant questions are those which children ask. See The Role of Questions on page 6 for further discussion of this topic.

2. *Experimenting.* An experiment is a way of finding out; it is not an end in itself. In an experiment the materials are carefully selected, and the conditions are carefully arranged. This is different from an *experience* in which the materials and events are observed in the natural world. An experiment is a technique through which man tries to discover nature's secrets.

For example, when children test for the presence of carbon dioxide in air, they leave some limewater in a small, open jar overnight and find that it turns milky. To establish that the milky appearance of the limewater was actually caused by the carbon dioxide *in the air*, they set up, as a *control*, a closed jar of limewater. It should remain clear overnight.

Children should be encouraged to devise their own experiments. It will be helpful for the teacher to ask frequently, "How can we find out . . . ?" Indeed, the children's involvement in planning an experiment is just as important as doing the experiment. They should plan, if possible, to test a single factor at a time.

For example, if they wish to find out how to prevent the rusting of iron, they may suggest treating iron nails with such substances as oil paint, aluminum paint, oil, or fingernail polish. They then keep all of the nails under identical conditions of moisture, temperature, light, and air; and observe them at regular intervals. In this experiment all conditions are the same but for the coating on nails.

3. *Predicting*. Children should be encouraged to predict results, to propose explanations, and then to test them. Predicting results will help children focus their thinking on a problem. Checking results will help them evaluate their thinking. The process of predicting also adds excitement and a sense of playing a game to the learning of science. In the study of the "Ocean of Air," children predict whether the descent of a dropped, flat piece of paper differs from that of the same paper crushed into a small ball. They experiment to test their predictions, comparing the path of flight in the two instances, and the time of the fall.

4. *Observing*. This process involves making use of the senses to gather information. Children use their muscles and other parts of their bodies to make observations as they push, pull, put things together, and take things apart. The teacher encourages them to use all their senses when they investigate, and to report what their senses indicate. Sometimes they extend what they learn from their senses by using an instrument. A magnifying glass, for example, helps them see a grain of sand or a salt crystal in greater detail.

5. *Interpreting*. When perfume is poured into a dish at the front of the room, the children closest to the dish smell it first. Those farther away smell it a little later. Their *interpretation* is that the molecules of perfume move into the air, travel through it, and eventually are

dispersed throughout the room. The children also notice that the scent is stronger the closer they are to the dish of perfume. Their *interpretation* of this is that more perfume molecules are in the air over the dish than in an equal quantity of air at the other end of the room.

Children should be helped to distinguish between an observation and an interpretation. For example, in Molecules and Atoms, they snap a balloon over the neck of an empty soda bottle, and place the bottle in a basin of warm water. Their *observation* is that the balloon gets larger. Their *interpretation* is that, as the air in the bottle is heated, its molecules bounce more vigorously, and the air expands to take up more space.

6. *Measuring.* A very important aspect of experimentation is measurement. In investigating the question of how we can make an electromagnet stronger, the children test a number of hypotheses. In each case, they measure the strength of their electromagnet by counting the number of paper clips picked up. They are thus able to state their findings in exact units.

7. *Keeping Records.* Records are kept in many ways: in written words, maps, photographs, tape recordings, numbers, drawings, graphs, and in collections of objects. When children gather data and look at it, they begin to understand that many examples make generalizations more valid.

   For example, in the study of stars and constellations, children observe a given constellation's position in the sky every hour for several hours. They record its position in the frame of reference of familiar local landmarks, such as buildings, trees, church steeples, and so forth. Comparing the positions of the constellation, as recorded by their simple drawings, provides them with the basis for judging whether it appeared to move through the sky during the night.

8. *Classifying.* This process involves collecting and organizing objects or information. It may mean separating objects to find likenesses or differences. It involves comparing things and grouping them. Children should be guided to an awareness of the reasons for classifying objects: to simplify, to discover underlying or basic similarities and differences. Children should be encouraged to classify objects for their own reasons, and to use their own basis for classification.

Children compare the effects of using lenses in different combinations and at different distances. They pool their discoveries and arrange their findings in a chart.

9. *Generalizing.* At the end of each problem in the handbook, there are understandings and generalizations that children may suggest. These are based on their observations, experiences, and experiments. Throughout the work in science, children should be encouraged to generalize in their own words. This will make the process of forming generalizations one which involves careful, critical thinking.

THE ROLE OF QUESTIONS IN TEACHING SCIENCE

Good questions are the keys to good teaching in all curriculum areas. In science, questions have a special role since they are the starting point for children's investigations. In spirit, this is essentially the way in which scientists initiate research. Questions give purpose and direction to activity. Therefore, the science program outlined in this handbook is developed through problems that are posed as questions.

Children ask questions naturally. An important goal in science teaching is to encourage and cultivate this questioning attitude. *Children should feel that school is the place to ask questions, that their questions are important, and that questions often trigger exciting explorations.* The teacher helps set the stage by arranging for situations which provoke questions. By the kinds of questions he asks, the teacher also serves as a model for the children as they develop and improve their skill in questioning.

Answers are found in a variety of ways. Occasionally, the teacher, a book, or other children may provide answers. However, answers become more meaningful when children find them in the course of their own investigations.

Questions serve many purposes. Some useful opening question forms are:

What happens if . . . ?

How can we find out . . . ?

How can you be sure that . . . ?

In how many ways can we (do) . . . ?

How can we (do) . . . ?

Where can we find . . . ?

What happens . . . ?

And let us not forget to ask children, "What questions do you have?" and to counter children's questions frequently by asking, "What do you think?"

Children should come to understand that there are many questions for which there are still no answers. We are uncertain about the cause of the earth's magnetism. We do not know whether life exists on Mars. As children go on with their science studies, they will understand that all answers in science are man-made, hence subject to error and change. There is no final, absolute authority in science. This does not, however, deny the importance of the principles and theories which scientists construct to explain phenomena. But most significant principles and theories in science lead to the discovery of new principles and theories.

For the teacher the significance of this approach to answering questions in science is that children's ideas and proposals should be considered, and that the teacher need not become the authority or a spokesman for the authority. Rather, science in the classroom should be an adventure in which children and teacher participate. Children should come to regard science as an endless quest rather than a finite body of information. Following are some typical questions grouped to indicate their special character.

Questions which draw on children's experiences

What spaceships have you seen blasting off?
What kind of camera do you have?

Questions which lead to trips and surveys

How do dust and smoke in the atmosphere affect us?
Where are electromagnets used in our school?
How can we find the Big Dipper?

Questions which lead to close observation

What can we discover with a magnifying glass?
Do all stars in the sky look the same?

Questions which provoke experimentation

Can we change the poles of an electromagnet?
How can we make an electromagnet stronger?
How can we prevent iron from rusting?

Questions which help children group and classify

How many kinds of atoms are there?
What do different kinds of lenses do?

Questions which lead to measurement and collecting of data

Why do spaceships use several stages?
How can we make a model of the Big Dipper?

Questions which challenge children to propose ways of finding out

How can we break a lump of sugar into its tiniest pieces?
How can we test the strength of an electromagnet?

Questions which ask children to predict

What happens to the size of substances when they are heated?
What would happen to the poles of an electromagnet if we reversed the connections to the dry cell?

Questions which challenge children to propose explanations

Why does your hair sometimes stand on end?
How does gravity affect space flight?
Why is the image in a pinhole camera upside down?
Why do we see a Milky Way in the sky?

THE ROLE OF THE EXPERIMENT

The classic way through which man tries to discover nature's secrets is by experimenting. When children experiment, they are intrigued by the elements of surprise and discovery that are a part of such investigations. They begin to develop patterns of thinking and working which are characteristic of scientists. In the context of science teaching, we differentiate *experience* from *experiment*. Experiences may include the child's observing a jet plane taking off, examining a rough surface with a magnifying glass, or identifying a group of stars in the night sky. An experiment, on the other hand, is usually a cooperatively developed enterprise involving teacher and children, with appropriate materials set up for the purpose of finding the answer to a particular problem, such as "How can we make a stronger electromagnet?"

The significance of the experiment is that it helps the experimenter to find something out rather than to prove something. *Its character is more "Let's find out whether . . ." than "Let's prove that. . . ."* The teacher sets the stage by providing situations which stimulate children to raise problems. In a real experiment, there should be some doubt about the outcome in the investigator's mind. The experimenter may consider an outcome to be probable, but he is still unsure of it.

Although an experiment is conducted to solve a problem, every research scientist has had the experience of finding new problems during his experimentation. In their experiments, pupils also will open up many new lines of thinking; as they attack one problem, additional problems will be disclosed. Where feasible, therefore, the program of experimentation may be extended to include some new problems.

Guidelines for Experimentation

1. *The Setting*

The setting is provided by situations which develop from asking the trigger questions in the science handbook, from children's individual experiences, from class trips, from provocative materials, from previous experiments. All of these may result in problems or questions. For example, after children play freely with a number of lenses, they find that there are a number of different ways of changing the magnification. Later they try to discover how a lens can be used to make an image.

2. *Getting into Action*

The children should be given an opportunity to design the experiment and to decide on and gather the appropriate materials. Depending on the availability of the materials, physical conditions, and safety considerations, the experiment should be performed by pupils individually, by pupils working together, or by one group in the class. It is important that children have opportunities to manipulate the materials and to work at their own pace. Before proceeding with the experiment, the children should understand how the experiment is related to the problem.

3. *Making It Scientific*

Wherever possible, use a *control*. This is essentially a method of providing a basis for accurate comparison. When children try to find out how to make an electromagnet stronger, they propose increasing the number of dry cells connected to the electromagnet. If they start with one cell, this may be regarded as the *control*. They then hook up two cells to an identical electromagnet and compare the results (the number of paper clips picked up).

Test only *one* variable at a time. For example, when children experiment to find out if the number of cells affects the strength of electromagnets, the only variable should be the *number of cells*. The electromagnets tested should have the *same* number of turns of the *same* kind of wire wound around the *same* kind of iron core. If, on the other hand, children want to find out whether the number of turns of wire makes a difference in the strength of electromagnets, they should use the *same* number of cells, the same kind of iron core, and the same kind of wire in each of the electromagnets to be tested. The only variable here is the number of turns of wire. In this way, they can arrive at a conclusion that has validity.

Take advantage of the fact that you have a number of children who may perform the same experiment. It may be found that variations in the results children get are due to differences in the *techniques* used, variations in *observational skills*, differences in ability to *report* observations, or differences in the *materials* used (the use of a weak dry cell as compared to the use of a strong dry cell). Discuss these variations with the children; do not avoid discussing them. Variation is the heart of science. As one scientist said, "Cherish your exceptions."

Results of experiments should be recorded, reported, and summed up to help the children gain the most understanding from the experiments. The greater the number of experiments and observations, the greater the possibility of arriving at a valid explanation or generalization.

4. *When the Experiment Does Not "Work"*

In a sense, every experiment "works"; that is, what happens is a result of natural influences. For example, when children experiment with two dry cells connected in series, they may find that the connected electromagnet is weaker than it was before. *This is not a failure; it is an opportunity*. For here is a *real* problem, not one predetermined by the teacher. Asking the children how to solve this *real* problem leads to the highest level of experimentation because children are actually cast in the role of scientists. Something is working here—but not what is expected. Perhaps the connections are faulty. Perhaps one of the dry cells is "dead." Encourage the children to suggest why the experiment is working the way it does and to test their theories. Since, during a school year, many of the investigations suggested in the handbook will lead to situations in which something appears not to work, it is essential that the teacher capitalize on these opportunities for involving children in science learning.

MATERIALS FOR ELEMENTARY SCIENCE

For effective learning of science, children must have as many firsthand experiences with real materials as possible. To assist the teacher in planning, the handbook includes lists of materials that are necessary for each unit in Grade 6. In general, the lists are based on the assumption that children will work in groups of four, although there will be many occasions when the teacher may depart from this arrangement. The *Stocked Supply List* contains the items which may be ordered.

Sources

In addition to the standard type of science materials provided by the school, such as magnets, magnifying glasses, and thermometers, the teacher has many other sources, including materials in the classroom such as window pole, paper clips, drinking straws, and milk cartons.

Children can contribute science materials such as empty spools, leaves, pebbles, plastic containers, and shoeboxes. Local hardware, variety, and pet stores are sources of science materials. Other sources of science materials are museums and botanical gardens.

Since we continually emphasize conservation, children should be made aware of the need to discriminate when collecting science material outdoors. Whereas removing a fallen leaf from beneath a tree does no harm, leaves ripped from branches may injure a tree. Specimens on private property are not to be collected. Children in early grades should be accompanied by an adult on any field trip.

Storage

It has been found that no one method of storage is convenient for everyone. Shoe boxes and other containers may hold many materials for a particular unit such as the one on electricity. This may be part of the permanent equipment for your room. Expensive equipment should be stored centrally and should be available, on order, to classroom teachers. Schools may order cabinets containing tote trays for the storage of science equipment. Each school will select a method that best meets its needs.

Safety

The science safety bulletin is in all schools and should be consulted. The following rules apply particularly to the teaching of science in the elementary schools.

1. Materials must be safe for children. For example, plastic containers instead of glass containers should be used when possible.
2. Pupils should be under the direct supervision of a teacher at all times.
3. Devices or equipment brought in by a child should be pretested before use with the children.
4. Cautions in handling potentially dangerous materials, even if the teacher is demonstrating them, should be discussed. The science principles for safety should be discussed. For example, water and sand should be available whenever working with open flames.
5. Whenever possible, the safety applications of science principles should be taught. In the study of wheels and ball bearings, for example, a basis is developed for understanding the hazards of leaving round things on floors and stairs.
6. House current (110 volts) is NOT to be used. Only dry cells (1½ volts) are to be used for experiments with electricity.
7. Children are NOT to carry laboratory equipment or apparatus through the halls when classes are moving about.
8. Children are NOT to taste chemicals or other materials. The only exceptions are foods purchased and handled under sanitary conditions.
9. Children should be instructed to wash their hands after working with animals, plants, or plant materials.

SCIENCE AND THE READING PROGRAM

Children are fascinated by explorations in science, and this interest may be utilized in many ways to improve reading ability. The teacher can guide children to use newspapers, magazines, and books to satisfy their curiosity, and to enjoy the excitement of adventuring in science. In the early school years, youngsters respond to the "here and now" in their environment. From year to year, as new experiences introduce new science words, their speaking, reading, and writing abilities grow rapidly. For example, when they plan a garden, children consult planting instructions to find out how to sow and care for their plants. They become familiar with the names of many common seeds, vegetables, flowers, and gardening tools. Educationally disadvantaged children and those to whom English is a second language increase their English vocabulary as they learn words describing concrete objects and their use in science experiences. They are eager to tell others about their own experiences. The teacher should encourage this expression and use it in the science program.

Making Experience Charts, Oral and Written Reports, Graphs

Pupils are encouraged to describe in their own words what they want to investigate through their experiments, what they propose to do and to use, what they observe, and what they learn. The teacher or a pupil may print a summary chart as the children report their findings in each experiment. Once a child grasps the significance of such a statement, it will not take long before he can read the words of which the statement is composed. Gradually, he will gain the ability to write and read his own reports, thus further strengthening both science and reading skills.

Step by step, as children pursue their simple investigations, they are taught to prepare, read, and interpret charts, tables, and graphs which show the results of such measurements as weight, time, temperature, rainfall, and distance.

Preparing Exhibits

In the preparation of hall and classroom displays, children practice the skills required in writing and reading titles, captions, labels, and descriptive text. Much of this work may require that pupils read and follow specific directions. Through all of these science activities, reading is needed and used.

Implementing Reading in Science

Children should be given an opportunity to select reading material. The teacher should make available a variety of suitable books and other references in anticipation of a topic that may be studied, or as a source of information after a question. In this way, children begin to develop the habit of using many sources; they begin to appreciate the role of references in research. Printed matter in elementary science is available in five categories: textbooks, trade books, reference books, magazines, and free materials.

Since New York City has its own well-defined curriculum in science, no single textbook provides all readings essential in our program. Texts are used as references, for supplementary reading, for useful illustrations, and for techniques. For this purpose children should have available the texts of different publishers and at different grade levels.

Trade books, with their great diversity of subject matter, reading levels, styles, and formats, are excellent aids to the teacher in meeting the needs of individual children. On pages 236-245, grouped according to science areas, is an annotated Bibliography for children in Grade 6.

Reference books, such as encyclopedias, should be available, if possible, in the classroom and in the school library. Children need help, of course, in using these references properly.

Many manufacturers print material that may contribute to science learnings in elementary schools. Their public relations departments are cooperative in sending supplementary material to the schools. The usefulness of each publication must be carefully assayed before making it available to the children.

AUDIO-VISUAL MATERIALS IN THE SCIENCE PROGRAM

Since a large variety of audio-visual materials is available in our schools, the teacher can utilize a multisensory approach in the development of science concepts. These materials also motivate learning and make it more pleasurable. Thus stimulated, the pupils become more curious and begin to investigate, read, explore, and experiment.

Some aids, such as the chalkboard, the felt board, and the bulletin board, appeal to sight. The chalkboard, particularly, is available to every teacher and has great potentialities. To illuminate an idea, a large, clear sketch, in colored chalk if appropriate, is a fine teaching aid. The value of the chalkboard is enhanced if the teacher develops the drawing with the help of the children. The drawing grows as ideas grow, as children contribute to its lines and labels. The chalkboard makes it possible for all children in a group to center their attention on the same drawing while they discuss a problem. The pupils should be encouraged to use the chalkboard to explain and clarify their own ideas.

Motion pictures, filmstrips, and transparencies are used in various kinds of projectors found in the schools. Magazines and newspapers are good sources for pictures that may be hung in the classroom and viewed in greater detail by using the opaque projector. Charts and models that children make are often more meaningful than the commercial ones.

Other aids appeal to hearing. These include radio, tape recordings, phonograph records, sound films, and filmstrips. They offer the teacher additional opportunities for meaningful science lessons.

Television is a valuable teaching aid and can do much toward furthering the objectives of science teaching. The teacher should consult the TV guides provided by the Board of Education, and plan to use television as an *integral part* of his science program.

A teacher occasionally may use audio-visual materials to introduce a new unit or topic. Such use serves to stimulate the interest and curiosity of the children and helps them formulate the problems they will try to solve. Audio-visual materials may be used during the exploration of a unit or topic to supply information needed, to reinforce knowledge or skills, to stimulate research, and to encourage follow-up activities. These aids may also be helpful at the end of a unit to provide a review.

Audio-visual aids in science are primarily for instruction. Films and filmstrips are most effective when they can contribute specifically to the topic which is being studied. It is important that they be within the understanding of children of the grade and age level. It is not necessary that filmstrips be shown in their entirety; only those frames that are pertinent to the unit need be used. Projectors should be tested ahead of time to make sure that they are in working order.

If the children are adequately prepared for the material to be presented and are encouraged to be active participants, the learning is more effective. There should be ample opportunity for language training, oral and written. Children should be prepared for the new words anticipated by the teacher.

A follow-up program reinforces the knowledge and skills learned from the film, filmstrip, or other audio-visual material. This may take the form of creative writing, art work, trips to zoos and museums, making collections, reading science books, and making reports.

A list of audio-visual materials appropriate for the science topics in Grade 6 will be found on pages 222-235.

USING NEIGHBORHOOD RESOURCES

New York City is a wonderful laboratory for the study of natural science. Within the five boroughs such places as an ocean front, a bay, a waterfall, a river, and a swamp may be explored. Almost any neighborhood has a valley, a vacant lot, rocks, soil, plants, and animals. The school building itself with its natural and man-made stone reveals how man uses some of nature's resources. The schoolyard, exposed as it is to the sun, wind, and rain, is an exciting place for observing the seasons. The street becomes a rainshed area and the gutter a river bed whenever it rains. Sparrows, gulls, squirrels, and insects are among the wildlife that may be observed. A host of other wildlife abounds in nearby parks. The city's surface reveals its past; its rivers, lakes, rocks, and stones bear evidence of the glaciers which advanced over it until some 25,000 years ago. Located on the great Atlantic flyway, one of four main paths of migrating birds, New York City is a stopover for many of them.

In keeping with the principle that science for children should be rooted in firsthand experiences in the real world, neighborhood trips form an essential part of the science program. In this real world children see *real* buildings going up, *real* machines at work, *real* changes in the seasons, *real* stars and planets, *real* hills and valleys.

These guidelines for trips are suggested:

1. There should be a good reason for making the trip, and children should know the reason.
2. There should be planning for safety, transportation, time scheduling, collecting, note-taking, permissions.

3. The teacher should make a preliminary trip to determine the suitability of the place to be studied.
4. There should be group discussions about conduct and courtesy on the trip.
5. There may be some division of specific responsibilities for observing, collecting, and other simple duties.
6. Do not hurry children. A second trip to the same locale is often essential.
7. Follow-up after the trip may include discussion, displays, and reports.

THE SCHOOL GARDEN IN THE SCIENCE PROGRAM

The school garden is an outdoor classroom for science education. Here children can observe living plants in a natural environment of soil, sunlight, air, and water. It is a laboratory where children discover what plants need to grow, how plants grow under different conditions, what happens when plants are too crowded, how plants change as the seasons change.

For city children especially, the school garden is a place for many surprises and delights. Foods such as beans and peas, which may have been seen only in a can or a frozen-food package, are now seen growing and ripening on living plants. A salad made from radishes and lettuce freshly harvested by children from their own classroom garden is a rare treat. Carrots, turnips, Swiss chard, spinach, and peanuts are some of the other food plants which are easily grown in school gardens. There may be a harvest of the spring planting in June or of the summer planting in September. Not to be ignored are the exotic aromas and rich colors of garden flowers, which may be grown also.

As children work with garden tools, they learn about their proper use and care. They find out about the value of the hoe in breaking lumps of soil, of the rake for removing pebbles and stones and for smoothing the soil, of the sprinkling can (younger children) or hose (older children) for watering it.

Gardening experiences are relevant not only to the enrichment of other curriculum areas, but also to the development of interpersonal relationships. Recognition and understanding of a fellow planter's needs and desires grow as a gardening project develops. The school garden is also a laboratory in language arts, providing as it does a common basis for interchanging ideas, for discussing and writing plans, and for recording the observations that follow. Mathematics is used in planning and laying out the rows and measuring the growth of plants.

The school garden is a place where children observe the forces of nature at work. A downpour of rain makes gullies and washes away some of the precious topsoil; a drought dries the soil, makes it dusty, and causes the plants to wilt and droop. Children note that plants in the sunny part of the garden grow differently from those in less sunlight.

The school garden is an important resource. Here children learn of the dependence of man on plant and animal life and about the dependence of life on air, sun, soil, and water. When children see that what *they* do makes a difference, they have learned a prime concept of conservation.

EVALUATION

Evaluation is an integral part of the learning process. It begins when teaching starts and goes on long after a lesson or unit is completed. Success is revealed to the teacher by many signs. It may be simply the gleams in children's eyes or the smiles on their faces. In early childhood, success may be the painting and block building that children engage in following a science experience. It may be children's capacity to put a science principle to work in a new situation. It may be the number and kinds of questions that children ask. It may be their answers to such questions as, What are we trying to find out? What did we learn? It may be their skill in manipulating materials, or their involvement in long-range projects. It may be what children do after they leave the school building: hobbies they pursue, games they play, books they read, radio and television programs they select.

Science is both knowledge and process. It consists of *knowledge* in the form of facts and principles; it consists of the *process* employed by scientists: hypothesizing, experimenting, and generalizing. Science teaching is concerned with both of these characteristics. It is concerned, for example, with a child's knowing *that* a planet appears in different parts of the sky with the passage of time and with his knowing *how to find out* that it does. It follows that the evaluation of science teaching must take both of these facets into account. Since it is difficult to conduct tests for the *processes* of science, it is necessary for the teacher to employ other methods of evaluation, as indicated in the foregoing paragraph.

At the end of each topic in Grade 6, there is a section entitled Evaluative Activities. Teachers may use these questions and activities as models, selecting appropriate ones and adapting others. *The answers which are provided are typical and suggestive; the teacher should expect and accept other words and other ideas as well.* The illustrations suggest how questions and answers may be adapted for children with language difficulties.

It should be emphasized again that evaluation takes place all the time, not merely at the completion of a topic. *Evaluation serves as a sensitive instrument to guide the process of learning, moment by moment.* This handbook is designed to foster evaluation as a built-in characteristic of teaching and learning.

Some significant objectives and goals of the science curriculum are:

Objectives	**Goals**
Can children:	*Are children:*
1. set up experiments	1. increasing their interest in science
2. state the problem	2. increasing their awareness of the environment
3. suggest ways to solve a problem	3. reading science periodicals and books
4. manipulate materials	4. engaging in science activities on their own
5. record data	5. developing keener powers of observation
6. interpret data	6. seeking answers to their own questions
7. generalize from the results of an experiment	7. distinguishing fact from fancy
8. state new concepts	8. beginning to expect order and predictability in relation to natural phenomena?
9. apply these concepts?	

For the purposes of evaluation, *objectives,* as used in the preceding section, may be defined as the short-term, limited aims of a single topic or portion of the curriculum. *Goals* are defined here as the long-term, broad-scope aims of the entire science curriculum.

PLANNING FOR THE YEAR IN SCIENCE

Many teachers have asked for suggestions in planning their year in science. There can be no *one* way of scheduling that will apply to all teachers and children, since the placement, depth, and duration of any science topic depends on many variables: pupil interest, maturity, experiential background, language difficulties, unexpected and unusual happenings. Thus, a new moon mission will influence the scheduling of the Grade 6 study of *Moving in Air and Space.*

There are, however, certain constants which the teacher can depend on in planning science lessons: the logical sequence of science concepts, the sequence of themes which have been planned in other curriculum areas, the changing seasons, holidays, and other special days.

The sample schedules shown here reflect some of the constant factors which enter long-range planning. The teacher may use these as a guide, but should design her own plan to include the variable factors that enter into her own situation. Note that a topic may be taught in its entirety, without a break, or be subdivided into several subtopics to be taught at different times during the school year. It should also be noted that science lessons may occur without formal scheduling.

To summarize, the science schedule planned for the year should be structured to serve as a useful framework, but it should be flexible enough to meet the special needs of children, and to make the most of the unexpected and the unusual.

SAMPLE SCIENCE SCHEDULE

GRADE 6	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Light, Lenses, and the Camera	X	X								
From the Senses to the Brain		X	X							
Magnets and Electromagnets			X	X						
The Stars and the Universe				X	X					
Molecules and Atoms					X	X	X			
The Ocean of Air							X	X		
Moving in Air and Space									X	X

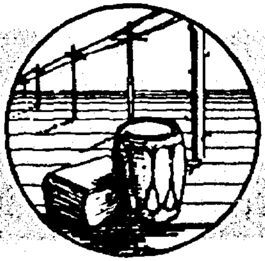
SEQUENCE OF SCIENCE TOPICS IN PREKINDERGARTEN — GRADE 6

The following table indicates the specific topics which are developed in Prekindergarten—Grade 6 in seven areas of science.

The topics in Prekindergarten are developed in *Prekindergarten and Kindergarten Curriculum Guide;* those for Kindergarten, Grades 1 and 2 in *Science: Grades K-2;* for Grades 3 and 4 in *Science: Grades 3-4;* for Grade 5 in *Science: Grade 5;* for Grade 6 in *Science: Grade 6.*

AREA	PRE-KINDERGARTEN	KINDERGARTEN	GRADE 1	GRADE 2	GRADE 3	GRADE 4	GRADE 5	GRADE 6	
Magnetism and Electricity 		A Magnet Holds On		Magnets	Electricity in Everyday Life	Finding Direction with a Compass	Batteries and Bulbs	Magnets and Electromagnets	Page 73
Earth in Space 		Spaces and Places Light and Dark		Sunlight and Shadows	The Earth and the Sun	Our Nearest Neighbor in Space: The Moon	The Sun's Family	The Stars and the Universe	95
	Science in Food Science in Body Movements All Kinds of Pets	What's Alive? Discovering With Our Senses Seeds and Fruits Discovering with a Magnifying Glass	Animals and Plants in Our Neighborhood	Animals and Plants in the Classroom	The Needs of Plants and Animals	Getting New Plants	Little Environments	From the Senses to the Brain	48

Sound and Light in Communication 		Sounds Around Us	Making Sounds		How Sounds Are Made	Sounds Travel: Sounds Can Be Recorded	Mirrors and the Reflection of Light	Light, Lenses, and the Camera 24
Weather 	All Kinds of Weather		Weather from Day to Day		Observing and Measuring Weather Changes	Weather and Climate from Season to Season	Climate and Weather	The Ocean of Air 159
Motion and Force in Transportation 	Science in Wheels Science in Block-building	Uphill and Downhill Seesaws and Balances	Moving on Land and Water	Moving in the Air	Friction, Gravity, and Motion	Moving Things More Easily	Making It Go	Moving in Air and Space 185
Earth and Its Resources 	Science in a Sandbox Science in a Pan of Water	Heat Changes Foods Getting Wet and Drying Water Mixes with Foods After It Falls Blowing Soap Bubbles		Water, Soil, Rocks, and Air	Rocks and How We Use Them	The Water We Use	How Man Changes Materials	Molecules and Atoms 125



Light, Lenses, and the Camera

USING LENSES

BACKGROUND FOR THE TEACHER

A lens is a device for changing the path of light. Usually it is a clear glass or plastic object shaped to have one or more curved surfaces. A drop of water, because it is clear and has a curved surface, can serve as a lens.

Lenses enable us to see views that range from the minute and intricate details of cell structure and microscopic life to the stars and galaxies of the universe.

There are two types of *simple* lenses. One that is thicker in the middle than at the edge is called *convex*. Usually such a lens magnifies the object and is used in reading glasses, microscopes, telescopes, and cameras. The magnifying power of lenses makes it possible to learn much about extremely small and very distant objects. A lens that is thinner in the middle than at the edge is called *concave*. Such a lens makes an object appear smaller and farther away. The concave lens is rarely used by itself. It is found in opera glasses, eyeglasses for nearsighted people, and sometimes in expensive combination lenses in cameras.

Light travels in straight lines in any one material. But its direction is changed if it passes obliquely from a material of one density, such as air, to a material of another density, such as water or glass. This is why a pencil or spoon, partially submerged in water, looks bent. The bending of light as it passes obliquely from one material to another is known as *refraction*.

Lenses are effective light-benders; they are shaped to refract light according to the function of the optical device they are used in. Lenses are ground to the proper shape.

By refraction, optical instruments change the apparent size of objects so we may view them in greater detail. A simple microscope (a magnifying glass) is just a convex lens. A compound microscope, of the type used by scientists and students, contains two or more convex lenses.

When objects are viewed through two convex lenses, they appear larger than they do when they are viewed through only one such lens.

The telescope brings into view very distant objects in the universe that unaided eyes cannot see. The refracting telescope contains lenses. Reflecting telescopes contain lenses and mirrors. Binoculars (opera or field glasses) are really two small telescopes fastened side by side, one for each eye.

APPROACHES AND LEARNINGS FOR THE CHILD

Children are intrigued by the magnifying glass. With it they can examine whatever is available from a grain of sand to the eye of a classmate.

Within the scope of this topic pupils experiment with different kinds of lenses. They use the lenses in different combinations, at different distances, and for different purposes. They discover how optical instruments are constructed.

From the activities suggested, children learn the following facts:

Lenses are made of transparent materials that have curved surfaces.

Concave and convex lenses affect what we see in different ways.

A convex lens is a magnifier.

A concave lens is a reducer.

Optical instruments help us see objects that are small or far away.

Optical instruments contain one or more lenses singly or in combination to help us see better.

1. How do we use a magnifying glass?

Provide each pupil with a magnifying glass (a convex lens) and a square of newspaper. Ask them to observe the paper through the lens. They may notice that the print appears larger.

a. Does the distance of the lens from the paper make a difference?

What happens when the lens is placed on the paper? (Letters are barely magnified.)

What happens when the lens is lifted from the paper? (The letters are magnified more. The farther the lens is moved, the greater is the magnification, to a certain point.)

What happens when the lens is moved still farther from the paper? (The letters blur.)

How can we make the letters large, but clear? (Move the lens closer to the paper until the print is clear. When the magnified letters are clearest, they are in focus.)

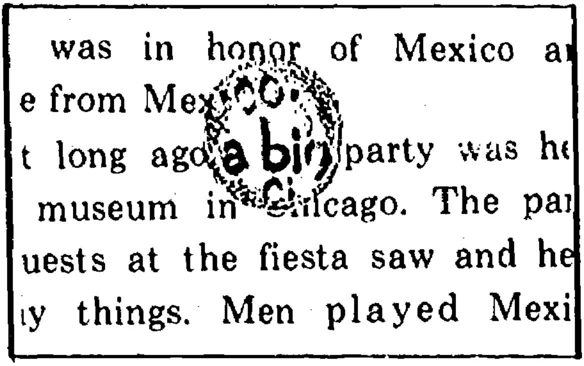
b. While an object is looked at through the lens (with the eye next to it), move the lens away. Are the letters still in focus? (No.) What must be done for the letters to be seen clearly? (Either move the lens back into place *or* lift your head so that your eye is farther away from the paper.) How does the lens help? (It allows you to bring your eye closer to the print.)

- *A glass with sides that curve out can magnify.*
- *A magnifying lens shows small things that cannot be seen otherwise.*
- *Moving a magnifying glass closer to or farther from the object helps to focus the view of the object.*

2. Can a drop of water be a magnifier?

In thinking about this question some pupils may recall observations they have made through a drop of water on their skin, on print, and on other surfaces.

Give each pupil a square of glossy paper on which there is print. (A section of a page from a magazine will do.)



Provide water in a cup. Ask pupils to predict what would happen if a drop of water were placed on the print. Suggest that they apply a drop of water by dipping a pencil into the cup and then allowing a small drop of water to run off onto one or two letters of the print. (A dull-pointed lead pencil or a pointed crayon pencil dipped in water forms manageable drops.) What happens? How do these letters compare with corresponding "dry" letters? Does the drop make letters larger?

Compare water drops of different sizes. (Drops can be enlarged by adding additional water with the point of the pencil.) Does making the drop larger magnify the letters more? (No.) Does a rounded drop magnify more than a flattened drop? (A rounded drop usually magnifies more.) What happens when the water is spread flat? (It does not magnify.)

- *Things look larger when they are viewed through a drop of water.*

- *A drop of water can be a magnifier.*

- *A raised drop seems to magnify more than a flatter drop.*

3. What else can we discover with our magnifying glass?

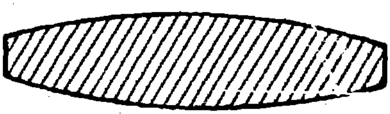
Ask pupils to suggest objects to be observed. Have them prepare a chart, such as the following, to summarize their findings:

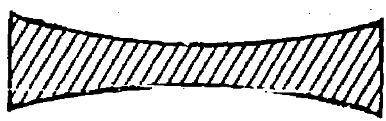
WHAT WE SAW THROUGH THE MAGNIFYING GLASS		
Object Seen	Drawing of Object	What We Learned
Table salt		Salt crystals are cubes.
Fingertips		
Hair		
Sand		
Phonograph record		
Soil		
Leaf		

- *The magnifying glass helps us see tiny objects.*
- *The magnifying glass helps us see tiny parts of objects which we cannot see otherwise.*

4. What do different kinds of lenses do?

Give each pupil a convex lens (one which curves *out* on each side) and a concave lens (one which curves *in* toward the center). Ask them to compare the shape of the two lenses. Children will discover by looking and feeling that the convex lens is thickest near the center and thinnest near the outside and that the concave lens is thinnest near the center and thickest near the outside. Ask the pupils to make a side view drawing of each kind of lens on the chalkboard.





Ask the children to look at a page of printed matter with each of the lenses, and compare what they see. They will discover that

The convex lens magnifies. The concave lens makes the type appear smaller (reduced).

The convex lens permits the user to see a smaller part of the page than a concave lens.

- *A lens which is thicker at the center is called a convex lens.*
- *A lens which is thinner at the center is called a concave lens.*
- *A convex lens is a magnifier.*
- *A concave lens is a reducer.*

5. What happens when we use two lenses together?

In this activity the pupils should be encouraged to use lenses in different combinations and at different distances. They should also be encouraged to look at different objects. (It may be necessary for groups of two or three pupils to pool their supply of lenses.)

Pupils may develop convex lens arrangements to better understand the microscope. Other arrangements may help them to appreciate the telescope. Pupils may find that by combining lenses in different positions they can develop telescopes, microscopes, and projectors. The results of their experimenting should be summed up in a chart. (See next page.)

Ask students to report on optical instruments, such as microscopes, telescopes, and field glasses. If possible, have a demonstration of these instruments. (Do not have pupils bring expensive devices to school.)

- *By using lenses in different ways the magnification and position (upside-down or right side up) of objects can be changed.*
- *Optical instruments, such as the telescope and microscope, are made of combinations of lenses.*

Evaluative Activities

Select the word or words that best completes each of these statements.

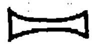
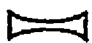
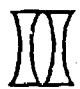
1. A lens with sides that curve out makes objects seen through it
   a. appear smaller.
   b. appear the same size.
   c. appear larger.
   d. disappear.

   (Answer: c.)

2. A lens magnifies because of
   a. its shape.
   b. its size.
   c. the kind of glass it is made of.
   d. its color.

   (Answer: a.)

WHAT LENSES DO

Lenses: Number and Type	Lenses: Picture	Object Observed	What Combination Does*	Similar To
1 convex		Newsprint	Magnifies	Magnifying glass
1 convex		Vase on other side of room	Makes vase look smaller and upside down	
2 convex		Newsprint	Magnifies more than one lens does	
2 convex (1 large reading glass, 1 small magnifier)		Vase on other side of room	Makes vase larger than without lenses; upside down	Telescope
1 concave		Newsprint	Makes smaller (reduces)	
1 concave		Chalkboard across room	Makes writing on it smaller; right side up	
2 concave		Newsprint	Makes writing on it smaller than 1 concave lens	
1 convex and 1 concave		Newsprint	Smaller than convex alone	

*Results depend on a number of factors, including shape and size of lens and distance. The chart gives samples of some observations; many others are possible.

3. A lens with sides that curve in makes objects seen through it

a. appear smaller.

b. appear larger.

c. appear upside-down.

d. appear the same size.

(Answer: a.)

MAKING A PICTURE

BACKGROUND FOR THE TEACHER

A convex lens, as we have seen, produces a magnified image of an object. The image is formed inside the eye of the viewer: light from the object is focused by the lens of the eye and "projected" on the retina. A convex lens can also project an image on a screen outside the eye. Convex lenses are used for this purpose in slide and filmstrip projectors, in motion picture projectors, and in cameras.

When light from an object passes through a convex lens, the light is bent to form an inverted image of the object. A pinhole camera, which has no lens, achieves the same result, but the image formed is much dimmer. A comparison of the size of the pinhole with the size of a lens emphasizes the advantage of the lens, which is a larger *light gatherer,* and consequently can produce a brighter image.

To make an image into a permanent picture, it is necessary to produce a chemical change. In a camera, light admitted by the lens produces a change in the silver salt embedded in a gelatin layer on the film. This change is made visible by developing, which produces the negative. In making a print, light is made to shine through the negative to the photographic paper which is also coated with a chemical sensitive to light.

Motion pictures are simply a series of still pictures projected on a screen in rapid succession. Each picture is motionless while it is being shown. The retina of the eye retains each picture for a fraction of a second, thus blending each image with the following one and producing the impression of continuous, lifelike motion.

Pupils experiment with lenses to project images on surfaces, such as a piece of paper. They make a pinhole camera and find that an image can be produced without a lens. They learn how to make permanent pictures by using blueprint paper and photographic paper. They construct working models to demonstrate the principle which makes motion pictures possible.

From the activities suggested, children learn these facts:

A convex lens can project an image of an object.

The image is upside-down (inverted).

A pinhole may be used instead of a lens to form an inverted image.

Light causes chemical changes in blueprint paper and photographic paper.

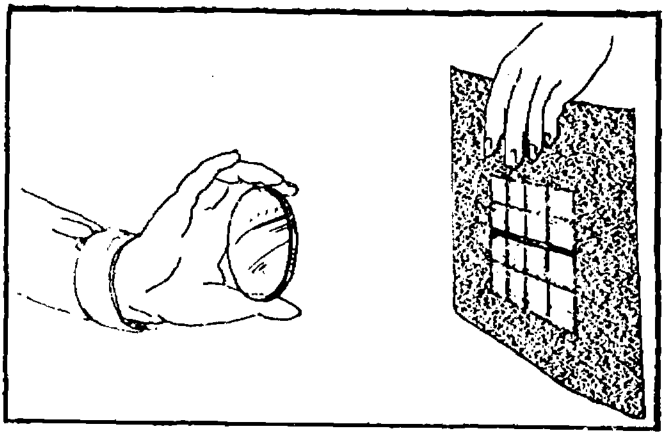
These changes help us make permanent pictures of the image.

In motion pictures, each individual frame is slightly different from the one before it.

Motion pictures seem to move because the eye blends each picture with the preceding and following ones.

1. How can we use a lens to make a picture?

Turn the room lights out. Ask the pupils to turn their backs to a window. Tell them to hold a sheet of white paper vertically with one



hand and a convex lens with the other. Then tell them to make a picture of the window appear on the paper by moving the lens back and forth. Is the picture smaller or larger than the window? (It is smaller.) Is the picture right-side up or upside-down? (It is upside-down.)

Have the pupils use the word *object* for the window and the word *image* for the picture on their paper.

If the paper is tacked to a bulletin board or temporarily taped to the wall or any other vertical surface, the pupils may be able to make a drawing on the paper, outlining the image that is projected on it.

- *A convex lens can be used to form (project) the image of a window (object) on a flat surface.*

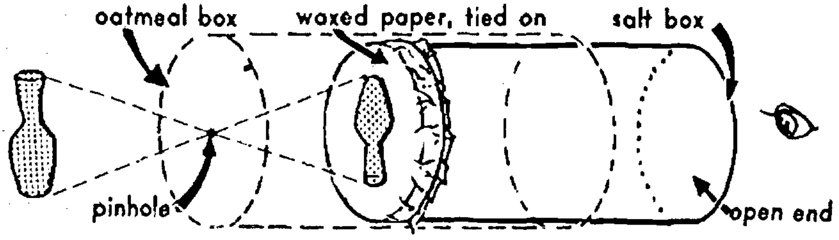
- *The image is smaller than the object and is upside-down (inverted).*

- *To focus the image it may be necessary to move the lens back and forth.*

2. How does a pinhole camera work?

The homemade camera described below is known as a pinhole camera and does not require a glass lens. In making and using this device children learn more about how light enters and travels in a camera.

Obtain two boxes so that one slides snugly into the other. These boxes may be cylindrical (cereal and salt boxes) or rectangular (shoe, candy, and cigar boxes). Wax paper over one end of the inner box serves as a screen on which the image falls.



Arrange the two boxes as shown in the illustration. Look through the back of the inside box at an object which is in strong light. Move the inside box in and out to see what happens to the image.

The class will notice that the image is upside-down.

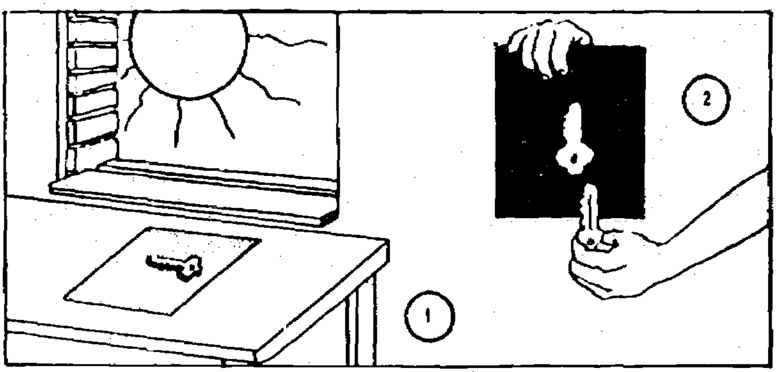
Why is the image upside-down (inverted)? Some pupils suggest that light from the upper part of the object must enter the pinhole at a slant and strike the lower part of the wax-paper screen (and vice versa).

- *The hole in a pinhole camera helps form the image.*
- *The image in a pinhole camera is upside-down.*

3. How can we make pictures on blueprint paper?

Blueprint paper may be ordered from the *Stocked Supply List*. It may also be obtained from blueprint equipment companies (see the classified telephone directory). Since this paper changes color when it is exposed to light, it must be kept in a light-tight container until it is used. (Even in such a container blueprint paper will slowly change color and lose its usefulness; fresh blueprint paper should be used.) Cut the large sheets into 3 inch squares in a semidark area, such as inside a closet. Give each pupil a square. Place the sheet of blueprint paper with the coated (slightly colored) side up, on a book or a board. Then place a key or other opaque object selected by the pupil on the paper. Set it in the sunlight until the exposed part of the paper changes color appreciably. Some experimentation may be necessary to determine the best exposure time. Place the exposed paper in a basin of water for several minutes. Dry the print by spreading it on newspaper.

Have the children observe the color changes in the paper. The finished blueprint shows a light-colored silhouette of the object on a blue background.



- *Light causes color changes in the chemicals of the blueprint paper.*
- *The part of the blueprint paper exposed to light darkens.*
- *The part of the blueprint paper not exposed to light remains pale.*

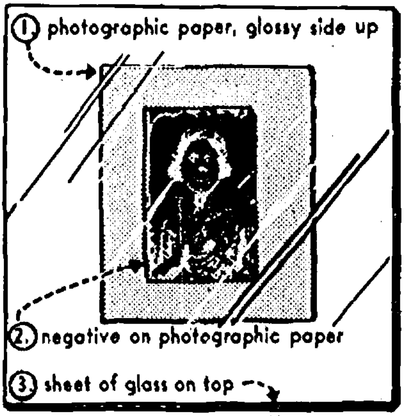
4. How can we make pictures from a negative?

Photographic prints may be made from negatives without the use of chemical solutions. Ask the children to bring to school negatives of pictures which they have taken.

a. Contact paper

The following is a demonstration of the use of contact paper in producing a photograph. ("Sun picture" kits, consisting of negatives and contact paper and sold in toy stores, may also be used.)

Place a special photographic paper, called printing-out paper (available from some photography supply stores) on a flat surface, with the glossy side up (1).



Position the negative over the paper with the dull side down (2).

Cover the negative with a sheet of flat glass (3).

Keep this arrangement in sunlight until the exposed parts turn a dark color. Try several exposures until a good print is obtained.

NOTE: Pictures developed by photofinishing companies are made permanent by further chemical processing.

b. Blueprint paper

Some children may suggest making a print from the negative with blueprint paper, which was used in the previous activity. Encourage them to experiment with the blueprint paper.

c. Chemical development

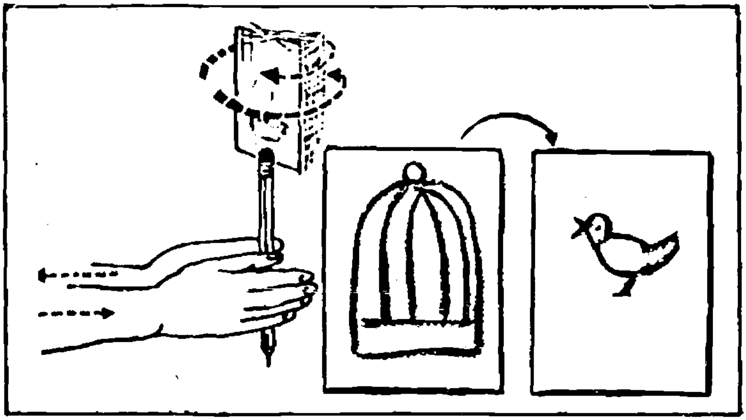
Some children may know how to make prints, using chemical developers. If it is possible, allow them to demonstrate this process in the classroom with the dark shades drawn.

Regardless of the method used to make prints, the children should examine the negatives and compare them with the finished prints. They will discover that the light parts of the negative produce dark areas in the print, and the dark parts of the negative produce light areas in the print.

- *Photographic paper is affected by light.*
- *The clear parts of a negative appear dark on a print.*
- *The dark parts of a negative appear light on a print.*
- *A positive picture, known as the print, may be made from a negative.*

5. How can we make two pictures appear as one?

Cut a rectangle 1½ inches by 2 inches from a library card or cardboard. In the center of one side of the rectangle, draw a bird cage. In the center of the other side, draw a bird. Insert the bottom of this card into a slit cut in an eraser at the end of a pencil as shown in the illustration. Ask the children to rotate the pencil between the palms of both hands. What happens? Where does the bird appear? (It appears in the cage.) Encourage the children to draw other pictures which may be combined

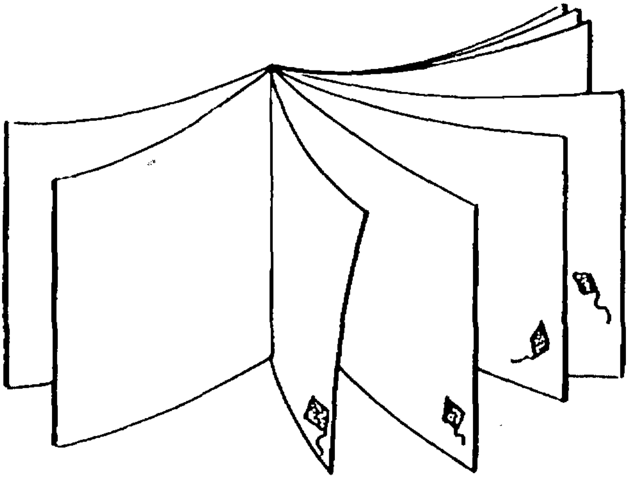


in the same way. Some examples are: a flower and flowerpot, a tiger in a zoo cage, candy in a glass jar, etc. Ask children to explain why they get this effect.

- *The eye continues to see a picture for an instant after it is removed from view.*
- *Two separate pictures can be "blended" by the eye to appear as one.*

6. How can we make still pictures appear to move?

With a pencil, draw a tiny object near the edge of a page in a small notebook or pad. In slightly different locations on each remaining page of the book place similar objects. Be sure that each location is slightly different from the location of the object on the preceding and following pages. Flip the pages with the thumb and index fingers, and see how the objects appear to move.

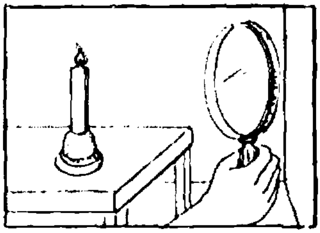


By using simple stick figures, the children can make "flip books" which tell stories. The growth of lima beans may be shown in this way by means of successively elaborated drawings.

- *In motion pictures, each individual frame is slightly different from the one before it.*
- *Pictures seem to move because the eye relates each picture to the preceding and following ones.*

Present these problems to the class.

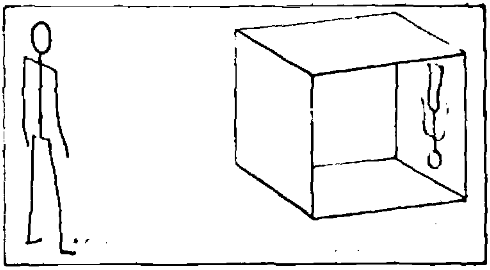
1. A boy uses a magnifying lens to project an image of a candle on a wall.



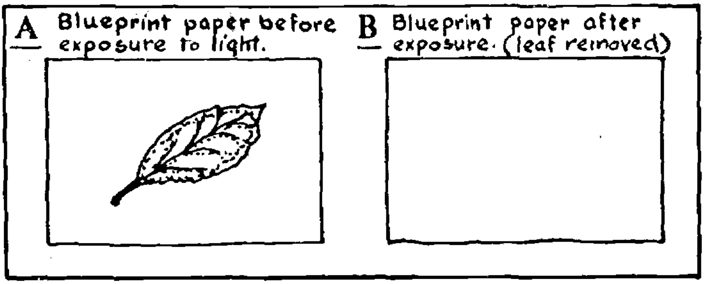
   a. Draw the image of the candle on the wall.
   b. Compare the *position* of the image with that of the object. (Image is upside-down.)
   c. Compare the *size* of the image with that of the object. (Image may be smaller, larger, or the same size.)
   d. If the image is not clear, how might it be sharpened? (Move the lens, or the candle, closer to or farther from the wall.)

2. In the diagram label:

   a. pinhole camera
   b. pinhole
   c. screen
   d. object
   e. image



3. A boy places a leaf on a sheet of blueprint paper (A). Show what the paper will look like in diagram B, after exposure to the light. (The place on the paper where the leaf was lying will be white. The rest of the paper will be dark.)



USING CAMERAS

BACKGROUND FOR THE TEACHER

The common box camera is essentially a light-tight box with a lens in front, an opening for light, a shutter for allowing light to enter the opening for a fraction of a second, a viewing device for composing the picture and a device for holding and turning the film. More expensive cameras also include devices for focusing the lens, for varying the size of the opening and for varying the period of time the shutter is open. These cameras may also have built-in exposure meters which measure the light intensity of the scene which is to be photographed and, in some cameras, devices to set the size of the opening automatically. Discussion of the operation of the camera will be found in the activities which follow.

APPROACHES AND LEARNINGS FOR THE CHILD

The camera is a scientific instrument of great value. Its importance lies in the fact that it can be used to photograph and record an event accurately, objectively, and permanently. It is an instrument of communication that the student himself can employ.

Many children in the sixth grade own and use cameras. They are eager to bring their cameras into class and discuss them. They are happy to show their snapshots and tell how they were taken. Boys and girls enthusiastically participate in picture-taking excursions and photo exhibits, often enhancing other areas of school work. The camera brings out talent and creativity in children.

From the activities suggested children learn these facts:

A camera is a light-tight box with a lens and an opening for light.

The lens forms an image on the film in a camera.

A camera makes it possible to obtain an accurate visual record.

1. What kind of camera do you have?

Ask the children who have cameras to bring them (unloaded) to school. Be guided by these rules with respect to the cameras:

a. Very expensive cameras should ordinarily not be brought to school.

b. Parents' permission should be secured.
c. Provision must be made for the safe storage of the cameras after they have been exhibited, until they are taken home at the end of the day.

The use of cameras should be demonstrated by their owners, and their main features should be discussed. The discussion should include comments about the size of the picture, how to snap the picture, how to look through the finder, and how adjustments can be made in the amount of light admitted. The class should be encouraged to ask questions, and if possible, they should see camera owners take pictures with the cameras they discuss.

- *There are many kinds of cameras.*
- *A camera is a light-tight box that has a lens, an opening for light, a shutter and a place to hold film.*
- *Some cameras can be adjusted for distance.*
- *In some cameras the size of the opening can be adjusted.*
- *In some cameras the time during which the shutter is open can be adjusted.*

2. How do we use a simple camera?

Ask a pupil who has brought in a simple box camera to demonstrate how he uses it. Ask him to show the class how he loads the camera with film; how he holds the camera firmly when he snaps the picture; how he uses the finder for good composition; how he gets proper lighting; how he focuses the camera (a box camera is prefocused but should not be used closer than six feet from the object); how other adjustments are made; how the shutter is snapped; how the roll of film is turned to the next exposure; and how the completely exposed roll is removed from the camera.

Ask him to bring in any pictures he has taken with this camera. Have the owner of the camera load it and take pictures of his classmates and scenes around the school.

In discussing other types of cameras brought in, lead children to understand that each one has the basic parts necessary for taking pictures.

- *It is easy to use a simple camera.*

- *The film must be inserted in a special way and must not be exposed to light.*
- *The camera should not move when the picture is snapped.*
- *The finder shows what the picture will include.*
- *The proper amount of light must be allowed to enter the camera.*
- *Simple cameras are often prefocused, but a minimum of six feet must be maintained between subject and camera.*
- *The film should be advanced immediately to the next number after a picture is taken.*

3. How can we take good pictures?

The following are examples of common photographic errors. Excepting the last picture, all photographs are used by courtesy of Eastman Kodak Company.

a. *Hold that camera!*

This is camera jiggle, a very common fault. Hold the camera firmly against your face or body and squeeze the shutter release *slowly*.

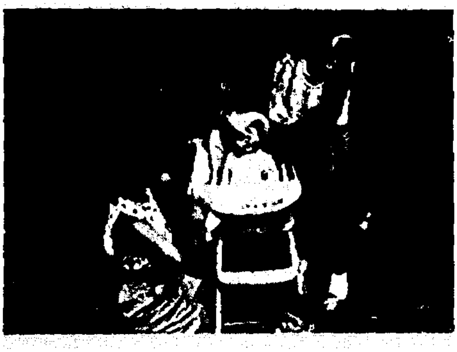
Set adjustable shutters at 1/50 or faster.

b. *Cotton-tufted borders?*

This is edge fog, usually the result of light entering a loosely wound roll of film. Load and unload in subdued light. Seal the exposed roll securely with the sticker. White blobs in the middle of a picture are usually from leaky bellows.

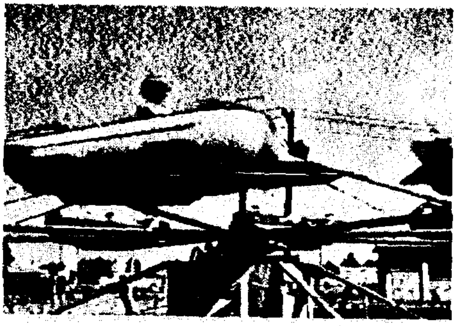
c. *Too light a diet of light?*

Dark or flat gray pictures result when too little light reaches the film. Use box or simple cameras only on sunny or cloudy-bright days. Inside, late in the day, or in shadows, use a flash bulb.



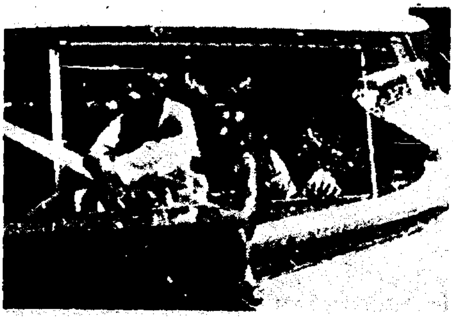
d. *Let's keep our heads!*

In close-ups, the camera lens and the viewfinder don't see exactly the same picture area. When you make pictures at 6 feet or closer, tip the camera up slightly to allow a little extra space at the top of the viewfinder.



e. *Just try to stop me!*

Some subjects have to be caught "on the wing". A shutter speed of $\frac{1}{50}$ second will do it in some cases, but it's safer to use $\frac{1}{100}$ or $\frac{1}{200}$. It depends on how close the subject is and in what direction the subject is moving in relation to the camera.



f. *Double exposure*

You took two pictures without winding the film. If you're not sure you wound the film, do it again. If you had wound it, you would lose only one piece of film. If you had not wound it, you would lose two pictures and a piece of film.

g. *Where are my bifocals?*

Don't have your subject closer than five feet from a simple camera unless you use a close-up attachment. If your camera has a focusing scale, set it for the main subject. In this picture the focus was set for the swimming pool instead of the girl.

h. *Poor composition*

Was the important thing in this picture the lamppost, the trash basket, or the boy with the pumpkin? Is there anything to interest us at the left? Would it have been better to wait until the truck at the top was out of the way?

Through discussions, dry run practice sessions with a camera, demonstrations of good and poor pictures, experiments involving the taking of pictures under varying conditions, and other means, the class can learn the following essentials for improving pictures.

Composing the Picture

Discuss and demonstrate good methods of posing or of arranging a scene. Evaluate certain stiff and unnatural poses. Find out how simple, uncluttered backgrounds enhance a picture. Some students may have special preferences for certain camera angles and unusual composition. Encourage this. Examine photographs in newspaper and picture magazines for examples of well-composed pictures. Discover that a good picture has a center of interest which captures one's attention.

Make a list of suggestions offered by the class.

Lighting

The class should know that there is a certain amount of light needed for a good picture. Too little light produces a thin, washed out negative with a lack of detail. On the other hand, too much light can produce a dark negative blocking out detail. Exposures made in heavy shadow, or early or late in the day may produce poor pictures due to inadequate light. Only complex cameras can be adjusted for difficult lighting.

When children discuss their own pictures as well as those in magazines, they should include the lighting conditions under which the pictures were taken.

Focusing

In order to get sharp pictures, most cameras must be adjusted for distance. Distance is usually indicated on a scale. Box cameras are prefocused to take sharp pictures from about six feet and beyond.

Questions to explore

What is a double exposure?

Why should one hold his breath while the shutter clicks?

What can damage a camera at the beach? (Sand and the heat of direct sunlight can damage a camera at the beach.)

How should a camera lens be cleaned?

How are flash pictures taken?

How is a time exposure taken?

How are moving objects photographed?

How may the amount of light entering the camera be controlled?

- *Interesting composition, correct lighting, and sharp focusing are needed for good picture-taking.*

- *A camera is a delicate tool and requires good care.*

4. When and where can our class take good, interesting pictures?

Have children talk about places the class may visit where they can use their cameras, putting into practice the knowledge and skills learned in previous lessons. They may mention trips to zoos and botanic gardens. A walk around the neighborhood will offer opportunities to photograph trees, street scenes, men at work, excavations, and other interesting subjects. Plan a class photography trip. Sharing cameras and the cost of film including developing and printing should be encouraged. A class exhibit of labelled and dated pictures taken on these trips may be prepared and evaluated.

- *Photographs are permanent records of places, people, things, and events..*

Evaluative Activities

Note whether the children

a. show more interest in photography.

b. take better pictures.

c. participate in photographic trips.

d. make photographic exhibits.

FINDING OUT MORE ABOUT CAMERAS

(Enrichment Activities)

These projects, problems, and investigations are for children with special interest or ability who may wish to pursue the subject further.

1. Take pictures of dramatic weather effects such as snowstorms, sleet storms, hailstones, fog.

2. Photograph objects of scientific interest such as trees in the neighborhood, birds' nests, seasonal changes in trees and shrubs, outcrops of rock, different kinds of vehicles, stages in the construction of buildings, length of shadows, results of erosion, types of clouds.

3. Learn how to make interesting double exposures.

4. Learn how to use an inexpensive portrait lens which clips over a box camera lens. This enables one to take closeup pictures of animals, flowers, and other objects at distances of from ten inches to about twenty inches.

5. Report on how to do trick photography. Bring samples of your work.

6. Demonstrate and discuss special accessories used by amateu photographers. Include tripod, exposure meter, flash attachmen and devices for taking one's own picture.

7. Show home movies at school.

8. Invent a remote control device for taking one's own picture.

9. Take some pictures of the same scene in the morning, at noo and in late afternoon.

10. Find out how to make pictures of star trails. This may be done b pointing an open camera toward a star (usually the North Star) for ten minutes or more. Work in a dark area away from stree and store lights.

11. Take a picture of the moon. Try different time exposures rangin from a few seconds to many minutes.

12. Report on the history of motion pictures.

13. Find out what tintypes are.

14. How long is one twenty-fifth of a second? Open an empty camera look through the lens as the shutter is snapped. Load a camer and take pictures of the same scene at different shutter speeds, such as $\frac{1}{25}$, $\frac{1}{50}$, and $\frac{1}{100}$ of a second.

15. Find out how pictures are taken and broadcast in a television studio.

16. Find out how pictures are reproduced in the home television receiver.

17. Take pictures of projects at school science fairs.

18. Take a photograph through a microscope and through a telescope.

BASIC SUPPLY LIST

For Light, Lenses, and the Camera

*Indicates quantity for entire class. Other quantities specified are for individual children or for groups of 2 to 4 children. (Individual work with materials is the most desirable procedure.)

STOCKED SUPPLY LIST

4 Convex lenses
4 Concave lenses
1 Hand lens, 4″ diameter
1 Lens support
* Pinhole camera
* 1 Package blueprint paper
* 1 Package photographic contact paper
* Microscope
4 Pencils with erasers
4 Medicine droppers
4 Glass plates
4 Small pads or notebooks

MISCELLANEOUS

4 Squares of newspaper
4 Glossy paper squares, printed
1 Paper cup or jar
* Water
* Table salt
* Sand
1 Phonograph record
4 Leaves
* Field glasses
* Telescope
4 Sheets of white paper
2 Boxes (one to fit snugly inside the other)
* 1 Roll waxed paper
4 Photograph negatives
4 Library cards

From the Senses to the Brain

THE SENSES

BACKGROUND FOR THE TEACHER

Most learning comes from the ability to see, hear, and feel. The senses make us aware of what is happening around us. Our senses include sight, hearing, touch, smell, and taste. The eyes, ears, skin, nose, and tongue are the special organs which receive the messages. Messages carried by nerves to the brain are called impulses. All impulses traveling along the nerves from the five sense organs reach the brain which interprets them.

The eye is sensitive to light. Impulses are produced by nerves receiving light passing through the eye and travel along the optic nerve to the brain.

The ear receives vibrations carried by the air and changes them into impulses conducted to the brain along the auditory nerve. The ear is divided into three sections: the outer ear, the middle ear, and the inner ear.

The skin possesses a variety of nerves. Some are sensitive to pressure, some to temperature changes, and some to pain. As these nerves are stimulated, impulses travel to the brain.

Nerves in the nose, called *olfactory* nerves, are sensitive to different substances in the air which produce odors. Once stimulated, the olfactory nerves carry impulses to the brain.

Scattered over the surface of the tongue are numerous tiny projections. These projections contain taste buds which have nerve endings at their base. The taste buds of the tongue are sensitive to four different tastes: sweet, salty, sour, and bitter. The taste of a particular food depends on its combined effect on several types of taste buds. When food makes contact with the taste buds, the nerve endings are stimulated. The sense of smell and sense of taste work together. Impulses from both these sense organs are sent to the brain where they are interpreted as one or more of the four types of taste.

APPROACHES AND LEARNINGS FOR THE CHILD

Through direct experience with their own senses, it is expected that children will learn these facts:

Our ears help us hear sounds.

The brain interprets the sounds for us.

Our eyes help us see.

We need light to see things.

The brain interprets what we see.

Through the skin we receive sensations of touch.

The sense of smell is important in tasting.

The tongue senses only sweet, sour, bitter, and salty tastes.

The brain interprets the messages that the skin, mouth, and nose send it.

1. What do our ears tell us?

Have children listen quietly for sounds they hear in the classroom. List these on the chalkboard or on a chart such as the following. Place a check in the appropriate column to indicate intensity of the sound.

SOUNDS IN OUR ROOM

Sound	Intensity of Sound	
	Loud	Soft
banging radiator		
dripping water		
breathing		

Prepare a similar chart under the heading .

SOUNDS OUTSIDE OUR ROOM		
	Intensity of Sound	
Sound	Loud	Soft

- *Our ears help us hear sounds.*
- *Our ears help us to know if a sound is loud or soft.*

2. Why is it better to have two ears rather than one?

Blindfold a child who is seated in the middle of the room. Station children in different parts of the room, and ask each in turn to clap his hands. Ask the blindfolded child to tell the direction from which the sound of the clap came. Then direct the blindfolded child to cover one ear with the palm of his hand. Repeat the sounds and ask him to identify the direction from which they come. When is he more successful in finding the right direction? Try this experience again with other children in the class. Keep a record of their results.

- *Two ears are better than one for hearing.*
- *Two ears find the direction of sound better than one ear.*

3. How do our outer ears help us?

Have a child stand up in the front of the room. Whisper a short sentence in his ear. Have him whisper the sentence to the class. Ask the children in the back of the room if they hear what he says clearly? If they hear, whisper another sentence in the child's ear and ask him to whisper it *very softly* to the class. If the children in the back of the room do not hear, ask them what they can do to hear better. They may suggest that the boy speak louder or that they move forward.

How else can they hear better? They may cup one ear. If they do not cup one ear, ask them what people hard-of-hearing often do. Have them cup one ear with their hand, and have the child at the front of the room whisper the sentence. Can they hear him now? Have them try again, this time cupping both ears. By which method do they hear better, Why does this happen? What part of our ear helps us to "catch" the sound?

How do animals such as the dog and the horse sound? Which part of the ear helps them to do this?

Ask them what would happen if there were no outer ear.

Make a megaphone from oak tag and have a child hold this instrument to his ear. Have him listen to sounds with it and without it. How do we hear better?

- *The outer ear helps to collect sounds.*
- *The outer ear helps us to hear better.*

4. What happens when we close the opening of the ear?

Have the class listen to the sounds made as individual pupils do the following things: tap the chalkboard with a pencil, crumple a sheet of paper, scrape shoes on the floor, clap hands.

Now ask members of the class to cover their ears with the palms of their hands and have them listen to the sounds suggested in the previous paragraph.

Ask children to press the *tragus* (knob on the cheek side of the ear) against the opening. Repeat the sounds made before.

What happens to the sound each time? What happens to sounds around us when we wear earmuffs?

- *Sounds travel through the opening of the ear to the inside.*
- *When the opening is clear, we hear better.*

5. How do our eardrums carry the messages?

Have children recall their experiences with sound in Grade 3. (See *Science: Grades 3-4*, page 77.) Repeat the experience in which chalk dust, dry cereal, or sand is sprinkled on a drum. When the drum is beaten, the drumhead vibrates, and the sand or chalk dust moves up and down. A homemade drum can be made by covering the open end of a can with a sheet of thin rubber, such as a balloon. Ask pupils what happens to the rubber sheet when we beat it. (It vibrates and makes a sound.) Explain to the children that inside the ear there is a membrane, similar to the rubber drumhead. When a sound is caught by the ear, it reaches this eardrum. Ask the children what happens to the eardrum. It vibrates, and the vibrations go further into the ear. Try to borrow a model of the ear which can be taken apart from a junior or senior high school.

- *The eardrum receives sound vibrations.*
- *The vibrating eardrum sends the vibrations to the middle ear.*

6. What is the role of the brain in hearing?

Prepare a chart such as this.

SOUNDS AROUND US			
	Location of Sound		
Sound	Inside Room	Outside Room	Cause of Sound

Ask children to sit quietly and listen to sounds without looking in the direction from which each sound comes. List the sounds they mention, and ask each one to tell you if the sound comes from within the room or from the outside. Ask them what makes the sound. When a fairly long list of sounds is made, have children explain how they decided what made the sound. Elicit from them that they remember having heard the sound before. Where is this remembrance stored? Pupils will probably say that the brain stores this remembrance. How does the sound reach the brain? What carries the vibrations to the brain? Some children may know that nerves at the end of the ear reach the brain. If they don't, explain that nerves act like wires in an electric circuit, carrying the impulses to the brain.

- *The brain stores memories of sounds.*
- *The brain interprets the sounds for us.*

7. How can we keep our ears healthy?

Discuss with the children how they can keep their ears in good condition. List their suggestions under the topic, Rules for Keeping Our Ears Healthy.

How do they feel when they have a head cold? What parts of the head are usually affected? Discuss how a nose cold affects the ears. Explain that blowing the nose hard, with the mouth closed, pushes air against the eardrums and may injure them.

Have children make two drums using rubber sheeting from a balloon. One sheet should be whole; the other should have a broken top. Tap each one and compare the sounds. Have children explain this rule: never put anything smaller than your elbow in your ear.

Place a tiny wad of paper on the unbroken drum. Play the drum gently. What happens to the wad of paper? Hit the drum harder. What happens to the wad of paper now? What happens to the eardrum when loud sounds are made?

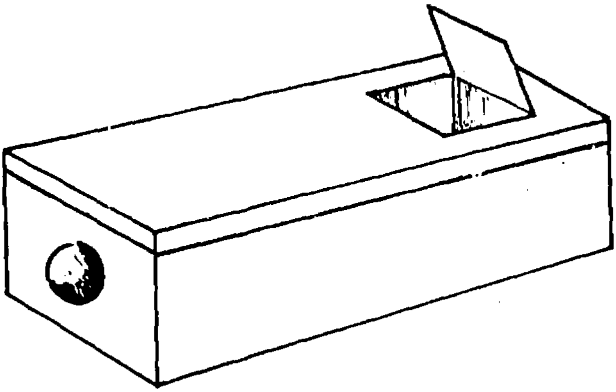
- *Forcing air against the eardrums may injure them.*
- *Placing objects in the ears may injure the eardrums.*
- *Very loud sounds may damage the eardrums.*

SEEING

1. Can we see things when there is no light?

While the children are busily occupied, put a dark object in a closet and shut the door. Have a child look into the closet as you open the door a crack. What does he see? (He sees nothing.) Open the door wider and have the child report on what he sees. Continue to widen the opening until the child sees the object. What is necessary for the child to see the object? (Children decide that light is needed.)

Try another experiment, using a covered shoe box. Line the inside of the box and the cover with black paper. Punch a hole about an inch in diameter in the front of the box. Cut a small flap in the cover and push the cover back into its original position.



Put a small, dark object into the box and cover it, keeping flap closed. Ask a child to look through the hole and tell you what is inside. Have another child try it. If neither child can see the object, ask if anything can be done with the flap. When the flap is lifted up, the object can be seen. Why? What enters the box when the flap is up? Light coming in through the lifted flap falls on the object and is reflected through the hole to the child's eye.

- *We need light to see things.*
- *We see things when light travels from them to our eyes.*

2. How does the eye control the amount of light which enters it?

Ask children what they do when a bright light suddenly flashes in their eyes. They blink. What part of the eye is involved in blinking? (The lid, which acts like a window shade, is involved in blinking.)

Pair the children and have them look into each other's eyes. They may know that the colored part of the eye is called the iris, and the small, black center is the pupil. Ask them to look carefully at the pupil, noting its size. Now have a pair of children walk to a bright window or other source of bright light. What happens to the pupil of the eye? How does it compare in size to what it was in the darker place in the room?

- *The eyelids protect the eyes from too much light.*
- *The pupil of the eye gets larger in dim light.*
- *The pupil gets smaller in bright light.*

3. How wide is your vision?

As one child looks straight ahead, another child stands behind him holding an object at eye level. He slowly moves the object forward on the right until it reaches the field of vision of the child being tested. As soon as this child can detect motion, he says, "Stop." Observe where the object is when it is first visible. Repeat the experiment on the other side of the child.

Make two hollow tubes, each about 1½ inches in diameter from 8½ x 11-inch paper. Instruct a child to hold the tubes to his eyes and to walk around the room. He will see clearly, but only straight ahead.

What is the value of being able to see objects other than those which are directly ahead?

Have a child stand in the center of the room looking straight ahead. Ask him to name all the children he can see without turning his head to either side.

- *Our eyes have wide vision.*
- *We can see on both sides as we look straight ahead.*

4. Do your left eye and right eye see the same thing?

Place a round can with a printed label on the table. From a distance of ten to twelve inches, look at it with both eyes open. Then quickly close one eye and see how it looks. Open that eye and quickly close the other eye. Repeat this procedure a few times in rapid succession. Your right eye will see a little section of the right side of the can that your left eye cannot see.

Hold a pencil motionless in front of you, and close first the left and then the right eye rapidly and repeatedly. The pencil will appear to be moving slightly from side to side.

- *Each eye sees slightly different parts of an object.*
- *Each eye sees objects from a slightly different angle.*

5. Can we judge distance with one eye as well as with both eyes?

Have one child hold the bottom half of a fountain pen, point up. Ask another child to close one eye and with his arm at full length try to put the cap on the pen in one quick movement. What happens? Now have him try to do this with both eyes open. What happens?

Try the same experiment with a tube of toothpaste and its cap.

- *We can judge distances more accurately when we use two eyes than when we use one.*

6. What is the role of the brain in seeing?

Ask the class which sense organ is involved in seeing. In experience No. 1 the children learned that it was necessary to have light in order to see. They learned that we see objects when light is reflected from them to our eyes. What happens to the light when it reaches our eyes? Refer to experience No. 2. How does it enter our eye? (It enters through the pupil.) Just as a camera catches light on a film, the eye catches it on the back of the eyeball. What is this area of the eye called? (It is called the retina.) Unlike a camera, the picture on the film cannot be removed. How do we know what's on the retina? What interprets the picture in our eye for us? (The brain interprets it.) How does this picture get to our brain? (It gets to the brain by nerves.) Explain to them that impulses travel along nerves to the brain, much as electrical impulses travel along a wire.

- *The brain interprets what we see.*
- *The eye is connected to the brain by a nerve.*

7. How can we keep our eyes healthy?

Discuss with the children why it is vital that they take good care of their eyes. Prepare a chart with a heading, such as Rules for the Care of Our Eyes.

Have the children list rules and record them on the chart. Ask children to copy these rules into their notebooks.

Rules for the Care of Our Eyes

1. Have plenty of bright light.
2. Be certain that lamps throw their light directly on your work.
3. Be certain that light falls from above over your shoulder and never glares into your eyes.
4. Hold your work about 12 to 14 inches from your eyes.

5. Protect your eyes from accidents.
6. Rest your eyes occasionally.
7. Avoid looking directly at the sun.

For copies of published suggestions for the prevention of blindness, send to the National Society for the Prevention of Blindness, Inc., 79 Madison Avenue, New York, N.Y. 10010.

- *It is important to take good care of our eyes.*
- *We must follow rules for keeping our eyes healthy.*

TOUCHING, TASTING AND SMELLING

1. What can we detect by touching?

Blindfold some children and have them touch and identify several objects, such as sandpaper, a bobby pin, a nail, a piece of silky cloth, and other available things. Have them describe the feel of each object they touched. Repeat the experience, covering the hand with a glove.

Touch the end of a child's forefinger with the point of a pencil. Ask the child what he feels. Touch the forefinger with the eraser end of the pencil. How does it feel now?

- *The skin can detect different objects by the feel of them.*
- *Through the skin you receive sensations of touch.*

2. What else can we detect by touching?

Have a child dip a spoon in ice and keep it there for a full minute. Then have him touch the arm of a classmate with the spoon. How does it feel? Have another child dip the spoon in warm water and then touch the arm of his neighbor with it. How does it feel?

Have another child touch the arm of his neighbor lightly with his finger. Now have him do it again, but this time have him press his finger down on the arm. Have the second child describe his sensations each time.

- *The skin receives sensations of heat and cold.*
- *The skin receives sensations of pressure.*

3. Are all parts of the skin equally sensitive?

Touch the finger of a pupil with a piece of ice (use an ice cube from the refrigerator). Then touch his wrist, the inside of his elbow, his forearm, his neck, and his lips with it. Ask him to describe how each touch feels. Does the ice feel colder in certain places on his arm? How does it feel on his lips? Which part seems most sensitive to cold?

Repeat the experience, using a few drops of hot water. Which part seems most sensitive to heat?

- *Some parts of the skin are more sensitive to touch, heat, and cold than others.*

4. Can you tell an onion from an apple?

Blindfold a child. Hold a cut onion near his nose, and place a thin slice of apple in his mouth. Ask him what he is eating.

Blindfold another child. Ask him to hold his nostrils tightly closed. Put a thin slice of onion in his mouth. Have him guess what is in his mouth.

Blindfold another child, and as he keeps his nostrils tightly closed, put a piece of apple in his mouth. Ask him what he is eating.

- *The sense of smell is important in tasting.*
- *A stuffed nose, resulting from a cold, dulls our sense of smell and makes our food tasteless.*

5. What do we taste with the tongue?

Make solutions of salt, sugar, vinegar, orange juice, water, milk, powdered cocoa, and other foods. Blindfold a child. Ask him to hold his nostrils tightly closed. Have him taste the various foods, rinsing his mouth with water after sampling each solution. Have him describe what he tastes each time.

Have children classify each taste sensation as one of the four basic ones: sweet, sour, salty, or bitter.

- *The tongue senses only sweet, sour, bitter, and salty tastes.*

6. What is the role of the brain in touching, tasting, and smelling?

Ask children how they know what they have touched, tasted, and smelled. What part of the body interprets our sensations? (The children will probably say the brain.) How does the brain receive the reports of the things that touch you, that you smell or taste? Lead the children to understand that the nerves of the skin, nose, and mouth carry impulses to the brain very much like electrical wires in a circuit. The brain interprets these impulses for us.

- *The brain interprets the messages that the skin, mouth, and nose send to it.*

THE BRAIN

BACKGROUND FOR THE TEACHER

The brain is an integrated unit controlling all body activity. It is remarkable in its ability to do many things at the same time. While reading a book, one can be listening to music, eating an apple and tapping a foot, for the brain allows one to do several things simultaneously.

The brain is made up of billions of nerve cells. Oxygen and food are supplied to these cells by many blood vessels. Nerves carry messages from the sense organs to the brain. Not only does the brain receive sense messages, but it also sends commands to the muscles. It regulates the heartbeat and breathing and also controls the sense of balance.

The brain is made up of three main parts. Each part does its own kind of work, but many jobs are shared by all parts. Particular regions control the performance of specific body activities. There are centers for sight, smell, taste, sound, pain, speech, and muscular movement. There are areas for memory, reasoning, consciousness, and thought.

A number of the brain's functions have been duplicated by computers. Both brains and computers can process information they receive and sort out what is relevant in a particular situation. Both work on electrical circuits. There is however an extraordinary difference between the brain and computers. While all computers can solve some kinds of problems even better than the brain, not one of them has the brain's capacity for storing information and for creative thought.

APPROACHES AND LEARNINGS FOR THE CHILD

In this introduction to the relationship between the senses and the brain, the children will be led to understand these facts:

Our five senses are connected to the brain by nerves.

There are five sense centers in the brain.

There are special centers in the brain for memory, judgment, and understanding.

The brain stores information in its memory center.

Our experiences are the source for information filed in the brain.

The brain and the computer use stored information to solve problems.

1. What are the nerves that carry sensation connected to?

Discuss the following accident with children.

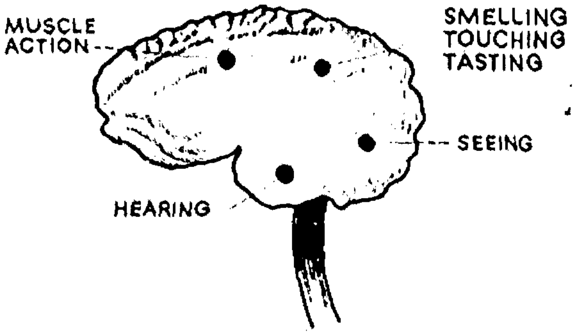
People are riding in a car when it becomes involved in a serious accident. After the accident one of the passengers complains that he cannot see. Examination by a doctor shows this man's eyes have not been damaged. The nerves leading from his eyes to the brain have not been injured. Yet the man cannot see. Another passenger has become deaf. A doctor's examination shows that nothing happened to the ears nor to the nerves from the ear to the brain. Why is this so? Where was the damage really done? Discuss the possible sources of injury and have children understand that injury to certain parts of the brain causes blindness and deafness.

Ask children to bring in a report describing the location of the areas in the brain where the sensory centers are found. If possible, have them make a simple map of the brain locating these sensory centers.

- *Our sense organs are connected to the brain by nerves.*
- *Nerves from sense organs end in a special area of the brain.*

2. Where are the sensory centers located in the brain?

Children give their reports as requested in experience No. 1. Have a capable child make an outline of the brain on a large chart. Have children in the class direct him in labelling only the five sense centers.



SERVICE CENTERS OF THE BRAIN

Have children copy the diagram on the chart into their notebooks for future reference. If possible, borrow a model and/or chart of the brain from a nearby junior high school.

- *There are sensory centers in the brain.*
- *Each sensory center is located at a special place in the brain.*

3. What other centers are located in the brain?

Ask the children if we can function only with our five senses. Give them the following example to consider: A boy is riding a bicycle and hears a strange sound coming from part of the bicycle. He stops, gets off, investigates, and discovers what is wrong. He decides that he cannot ride the bicycle in safety. Why does he make this decision? Elicit from the children the idea that the boy, in the past, found a similar defect in his bicycle when he heard the same sound.

Give them another example. The class is working in their room, and suddenly a gong rings several times. The teacher immediately instructs the children to stop work and get their clothing. The children line up as instructed and wait for another series of gongs. Then they file out quietly to assigned places in the yard. How does the teacher know what to do? Why do the children follow directions from the teacher when a gong is sounded?

Discuss with the children that they have memories of such past experiences which help them know what to do. Refer to the diagram developed in experience No. 2 and ask children to locate the centers of memory, judgment, and understanding. Label these areas.

- *There are special centers in the brain for memory, judgment, and understanding.*
- *Any act requires use of more than one center.*
- *Centers working together as a team make our actions possible.*

4. How does a computer work?

Have children tell about their experiences with computers. Many have seen computers in action at the World's Fair or at exhibits such as the one at the IBM center. Have any of them seen computers in school? Where? Teaching machines used for mathematics instruction are computers. Ask children how these machines work. Elicit the idea that cards with information are fed into these machines and are stored there. When the computer is asked a question, the answer requires the information stored on a number of cards.

- *A computer uses information stored in it to give an answer.*
- *An answer from the computer may depend on a number of stored facts.*

5. How is the brain like a computer?

Have the children pretend that they are sitting in the auditorium preparing for an assembly program and that your desk is the piano. Simulate striking a chord on the piano and make an appropriate musical sound. In all probability the children will stand ready to salute the flag. Now give the order, "Class, salute" as they face a flag in the room. After the pledge of allegiance, simulate a chord again for the children to sit down.

Discuss with them what made them act as they did. When did they learn to stand up or sit down at the sound of a chord? How many times did they have to practice these motions to learn them? How did they learn the pledge of allegiance?

Ask the children what they think happens in the brain when they repeat an action over and over again. Explain that the brain makes a record of these actions and files it away. The brain stores these records and uses them when necessary.

- *The brain uses information stored in it.*
- *Our experiences are the sources of information filed in the brain.*

6. What is the role of the brain in solving a problem?

Say to the class, "I will give you a problem that you will work out in your head. The problem is to multiply 12 x 9. When you have the answer, do not call out; raise your hand." Then call on a child to give his answer.

Ask the class to trace the path of the teacher's message from the time they hear the problem to the time they give the answer. Write the step-by-step responses on the board.

Ear receives problem.
Hearing center in brain receives message.
Memory center in brain recalls multiplication tables.
Motor center in brain tells child to raise his hand.
Speech center is stimulated.
Answer is given orally by vocal cords and mouth.

- *Problems are received by one or more sense organs.*
- *The nerves from the sense organs carry the message to the brain, as wires carry electricity.*
- *Messages are switched to different centers in the brain.*
- *The centers in the brain, working together, help us arrive at an answer.*
- *The nerves stimulate muscle centers.*

7. How does a computer act like a brain?

Refer to experience No. 4 and review how the computer works. Compare the brain and the computer using a chart. (See next page.)

After the children recognize the similarities between the brain and the computer have them discuss the important differences. Have them talk about thinking, judging, inventing, and feeling. How do the brain and the computer function in relation to each of these activities?

- *The brain stores information in its memory center.*
- *The computer stores information in its memory center.*
- *The brain and computer use stored information to solve problems.*
- *There are important differences between the functioning of the brain and that of the computer.*

BRAIN		COMPUTER
Sense organs receive the problem.	Input	The receiving center receives the problem.
Various centers, using previously stored facts, supply needed information.	Process	Facts previously stored in memory center of the computer provide the needed information.
Solution to the problem is produced.	Output	Answer to the problem is produced.

KEEPING THE BRAIN IN ACTION

BACKGROUND FOR THE TEACHER

The billions of body cells must have oxygen and food and a way to get rid of waste materials. The blood meets all these needs. The heart and lungs play a vital role in keeping all parts of the body healthy and in good working order. Cells, particularly those in the brain, cannot live without oxygen for more than a few minutes.

The heart, located in the center of the chest, is a pump receiving blood from all parts of the body and then pumping it to the lungs. There the blood receives a fresh supply of oxygen, returns to the heart, and is pumped out again to all parts of the body. The pumping of the heart keeps the blood moving. Exercise increases the heart action and the flow of blood. The body needs oxygen to change food into energy. During exertion the cells need greater supplies of food and oxygen and the heart beats faster and harder speeding up the flow of blood through the body. Heart action can be felt in the pulse which beats between 70 and 85 times a minute at rest. After exercise the pulse rate increases.

At rest the breathing rate is about 16 to 20 times a minute. During exercise the body needs more oxygen. The lungs are filled more completely more often, and breathing becomes faster and deeper. One of the wastes of the body is carbon dioxide which is carried away from the cells by the blood. This carbon dioxide stimulates the part of the brain that controls breathing. As the amount of carbon dioxide increases, breathing becomes deeper. During exercise more carbon dioxide is produced. The brain is stimulated and sends signals to the lungs to deepen breathing and more fresh air is taken in.

APPROACHES AND LEARNINGS FOR THE CHILD

Further investigation of the systems that support the functioning of the brain, will reveal to the children these facts:

Protein foods are needed by the brain.

The lungs take in air as we breathe in.

Air is very necessary for the brain to function properly.

The heart acts like a pump.

Exercise increases the number of heartbeats.

All parts of the body, including the brain, get more oxygen during exercise.

1. How does good nutrition help the brain?

Ask children what foods they eat. List these on the board. Discuss with them the foods that are especially good for developing strong bones and teeth. These foods include all milk products. What food is especially beneficial for sight, especially at night? They may mention carrots which are rich in vitamin A. Explain that all parts of the body need good food, but some foods are especially needed by certain organs: Ask them if they have read or heard that one food group is particularly necessary for healthy brain development. They may or may not know that *protein* foods are very important. Go down the list of foods on the board and circle the protein foods. They will be the meat, fish, eggs, poultry, cheeses; beans, peas, nuts, and whole grain cereals. Suggest that at least one of these be included in their daily diet.

Have pupils prepare picture charts of foods containing protein. These pictures may be obtained from newspapers and magazines. Have them label each food picture.

- *Food is necessary for a healthy body.*
- *Certain parts of the body need special food.*
- *Protein foods are needed by the brain.*
- *Proteins should be included in a daily diet.*

2. Where are your lungs?

Have children locate their ribs. Ask them to describe how the ribs feel. Are they hard or soft? Explain that all the ribs together make up what is called the rib cage. Why is this cage hard? What is found inside this cage? They may answer the heart and the lungs. Why is this cage made of thin ribs instead of solid bone? Elicit from them that the lungs expand and contract in breathing, and solid bone does not allow for this expansion and contraction. Ask the children why they have lungs. They will probably say, "To breathe." What do they breathe? They will say, "Air." How many lungs are there? How large are they? Ask children to hold their hands around their ribs and breathe deeply in and out. Repeat a few times. What happens to the ribs? Why does this happen? What do they think happens to the lungs as they breathe in? What happens as they breathe out?

- *There are a pair of lungs in the chest cavity.*
- *The lungs take in air as we breathe in.*

3. What is the effect of exercise on the rate of breathing?

Arrange the children in pairs. Ask them to observe each other as they breathe. Have them understand that by a breath you mean only an inhalation. Explain that you will tap to let them know when to start counting breaths and tap again when they are to stop. Have them count the number of breaths in one minute. Repeat this count for verification. Let each child write down the number of breaths his partner takes. Ask the class to stand and run in place for one minute. Have them sit down immediately, and at a tap from you, start counting breaths again for a minute.

How do the number of breaths before and after exercise compare? Is the number the same, more, or less than at rest? When is the breathing deeper, before or after exercise? Have the children discuss the body's need for more oxygen during exercise. This need is supplied by deep breathing and increased breathing rate.

- *We take about 16 breaths a minute at rest.*
- *The rate of breathing is increased after exertion.*
- *We breathe more deeply after exercise.*
- *The body needs more oxygen which the lungs supply during exercise.*

4. How do your lungs help your brain?

The children know that air is taken in by the lungs. Ask them what part of the air is the most important for the body. (The oxygen in the air is the most important.)

What happens if they are deprived of a good deal of the oxygen they need? What can they do to get more air? (They gasp.) What are they gasping for? (They need air.) What physical symptoms do they have as they gasp? (Faintness, dizziness, choking are some symptoms.) If only a small amount of air is available, what might happen to them? (They might faint.)

Talk about men who are trapped in a mine or a submarine and who have enough food and water to last for a long time. Yet people rush to rescue these men. What are people afraid they may be running out of?

Ask the children for their comments as you present the following incident:

A fire breaks out. People are trapped in smoke-filled rooms. The firemen who reach these people find them unconscious but not burned. Why are they unconscious? How do the firemen revive them? What happens to the firemen sometimes? What do their buddies do? What do they need to regain consciousness? What part of the body signals the mouth to open, to gasp for more air? What part of the body makes a person unconscious when there isn't enough oxygen to breathe? What part keeps us alert or conscious?

- *The lungs receive oxygen as we breathe air.*
- *The lungs supply oxygen for use in all parts of the body.*
- *Oxygen is necessary for the brain to function properly.*

5. What is the location, size, and shape of the heart?

Have each child locate his heart. Suggest that he place his hand in the center of his chest over the breastbone and try to feel the heart beating.

Give a pair of children a piece of oak tag or a piece of writing paper and a rubber band. Ask them to roll up the paper to form a tube and slip the rubber band around it to keep it from unrolling. One child should put one end of this tube against the other child's chest and hold it in place by putting his ear to the other end. Admonish the child to keep his hands off the tube. Ask the child who is listening what he hears. The room should be quiet because the heartbeat is a soft sound. Where is the heart located? (It lies in the center of the chest with its point a little to the left.)

Have each child make a clenched fist and hold it in the center of his chest. This is the approximate size and shape of the heart. Request a model of the heart and a stethoscope from your school, or borrow one from a local junior high school or high school.

- *The heart is located in the center of the chest.*
- *The heart is about the size and shape of a fist.*

6. What does the heart do?

To show the pumping action of the heart, try this experiment in a sink or deep basin.

Put your hands together to form a cup. Place your hands just under the surface of the water so that the cupped hands fill with water. The bottom of this cup should be completely closed. Squeeze your hands together suddenly, but do not close the top of the cup completely. A stream of water will spray up.

Have children understand that the heart works like a pump. What does this pump push around the body through tubes? (It pushes blood.) There are two important substances that the blood carries to all parts of the body. They are food and oxygen.

- *The heart acts like a pump.*
- *The heart pushes blood containing food and oxygen through tubes in the body.*

7. What is the effect of exercise on heart action?

Have the children take their own pulse by holding the first two fingers of the right hand lightly against the inside of the left wrist. Tell them you will tap when they are to begin counting the beats and tap again after 15 seconds. How many beats did they feel? Do it again once or twice and ask each child to write down the number of beats he felt. Ask each child how many seconds there are in a minute. They counted the beats for only 15 seconds. How could they find out how many beats there would be in a minute? Have them understand that they must multiply the number of beats they counted by four.

After determining their pulse rate at rest, have children stand up and jump up and down in their place 20 times. Explain that at a tap from you they are to start counting their pulsebeats and to stop at your next tap. Have them calculate the number of beats in a minute, again using the number after jumping. Is the number the same, more, or less than when they were at rest? How do the beats compare in strength before and after exercise? Why do they think there are more and stronger heartbeats during exercise?

- *Heartbeats can be felt in the pulse.*
- *Exercise increases the number of heartbeats.*
- *Exercise increases the amount of food and oxygen the body needs during exercise.*
- *All parts of the body, including the brain, get more oxygen during exercise.*

ENVIRONMENTAL HAZARDS

BACKGROUND FOR THE TEACHER

Only a few decades ago, people thought of air pollution in terms of smoke and soot. Now other wastes are known to be involved. Toxic gases and noxious particles have so contaminated our air that serious health problems have arisen. Respiratory diseases, such as emphysema, lung cancer, asthma, bronchitis, and sinusitis have increased to an alarming degree. Some sources of pollutants are cars, incinerators, home furnaces, oil refineries, power plants. Lungs deprived of clean air do not function efficiently, and the body is adversely affected.

Water pollution has become another serious problem especially in recent times. As a result of our technological "explosion," many industrial wastes are discharged into rivers, lakes, and ponds. As these waters eventually reach the ocean, it, too, becomes contaminated. Water pollutants include human sewage, industrial wastes, pesticides, and detergents. These pollutants affect living things, since they cause various diseases. In addition, fish and other seafood become contaminated and unfit to eat, thereby decreasing the available food supply. Many beaches become contaminated and are closed as unfit for bathing, thus depriving people of recreational activity.

With greater awareness of the effects of pollution on health, governmental action has now been initiated to control and lessen this hazard. Pollution can be stopped, and our environment can be made clean again.

APPROACHES AND LEARNINGS FOR THE CHILD

As children explore the aspects of the environment that can impair the functioning of their body systems, they will learn these facts:

Polluted air contains harmful substances.

Polluted air harms the lungs.

Polluted air makes the heart work harder.

A weakened heart sends less oxygen to the brain.

Polluted water contains many harmful substances.

Polluted water affects many parts of the body and causes disease.

1. What is air pollution?

Children hear about pollution from radio and TV, and read about it in their newspapers. Ask them to list some of the pollutants (harmful gases, soot, and dust). Discuss with them where these pollutants come from. Among common sources are cars, buses, incinerators, home furnaces, power plants, oil refineries, and others. Ask children to bring in pictures for a chart showing such sources. Ask children for their suggestions for control of these sources.

- *Polluted air contains harmful substances.*
- *There are many sources of pollution.*

2. What are some affects of air pollution on the body?

Polluted air attacks lung tissue and destroys some of it. Discuss with the class the following questions: How does polluted air affect breathing? How does it affect the ability of the lungs to work properly? How does it affect the amount of oxygen that a person takes in with each breath of air? How does a reduced amount of oxygen affect the brain?

For information on the effects of air pollution, send for the *Air Pollution Primer*, issued by the National Tuberculosis and Respiratory Disease Association at 293 Schermerhorn Street, Brooklyn, N.Y. 11217. Write to Citizens for Clean Air, 502 Park Avenue, New York, N.Y. 10017.

What diseases of the lungs are linked to air pollution? (Some diseases are emphysema, lung cancer, asthma, and bronchitis.)

- *Polluted air harms the lungs.*
- *Polluted air causes respiratory diseases.*

3. How does polluted air affect the heart?

Review how the heart works. Recall that oxygen from the lungs enters the bloodstream and is pumped by the heart to all parts of the body. What happens to the amount of oxygen sent to the bloodstream by lungs affected by air pollution? Ask the children what the heart must do to make up for the reduced amount of oxygen. What permanent effect can this added burden have on the heart? As a result of the heart having to work harder to compensate for the loss of oxygen, it may show changes such as weakness and enlargement.

- *Polluted air contains less oxygen than clean air.*
- *Polluted air makes the heart work harder.*
- *A weakened heart sends less oxygen to the brain.*

4. What is water pollution?

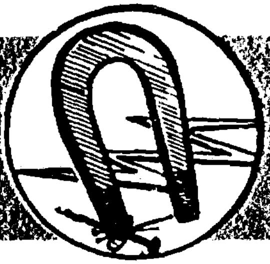
Discuss with the children why some of our beaches are closed. Have them list some of the unhealthy things found in water that make it unsafe. They may suggest garbage, oil, sewage, harmful chemicals, and others. List some of the sources of these pollutants. How do the pollutants affect us? What harm do they do to our bodies? Discuss how they irritate the eyes, ears, nose, and throat. How do they affect the intestinal tract?

Recently the presence of mercury in water has been publicized in newspapers. Where does this come from? (It is a by-product of paper manufacture.) How are we affected by it? Perhaps the children can tell you. If they cannot, explain that we eat the fish that have been exposed to mercury-polluted waters. Mercury may cause brain damage and mental retardation.

Make a picture chart of the sources that contribute to water pollution. Ask the children what people, including them, can do about the problem of water pollution.

For further information, suggest that the children write to the Information and Education Office, Division of Water Supply and Pollution Control, U.S. Public Health Service, Washington, D.C. 20007.

- *Polluted water contains many harmful substances.*
- *Polluted water affects many parts of our body.*
- *Polluted water causes disease.*



Magnets and Electromagnets

EXPERIMENTING WITH ELECTROMAGNETS

BACKGROUND FOR THE TEACHER

Man's early exploration of magnetism and electricity proceeded along two separate paths that merged near the beginning of the last century. Now we know that magnetism and electricity are related forms of energy, each one capable of producing the other.

Thus, when electricity flows through a wire, a magnetic force is set up. The force attracts iron and deflects a magnetic compass needle. A wire carrying such a current is called an electricity magnet, in short, an *electromagnet.*

When such a wire is formed into a coil, its magnetic influence is concentrated and strengthened. Inserting an iron core into this coil further strengthens the magnetism.

An electromagnet resembles a permanent magnet, such as the common bar or horseshoe magnet, in several ways:

1. It attracts iron.
2. It has a north pole and a south pole.
3. It is strongest at its poles.

An electromagnet has a number of advantages over a permanent magnet.

1. It can be strengthened by increasing the number of turns of wire, by increasing the electric current, or by inserting a larger core.

2. It is a temporary magnet; that is, its magnetism can be turned on and off as needed. This is helpful in such devices as magnetic cranes that can pick up and release loads of scrap iron.

3. Its poles can be reversed, thus making it useful as an electric motor.

NOTE: Read Suggestions for Making Dry Cells Last Longer, page 77, and review the unit on electricity, pages 189 to 217, in *Science: Grade 5*.

APPROACHES AND LEARNINGS FOR THE CHILD

Experiments with electromagnets introduce children to a basic component of many devices which make an industrial society possible. At the start of the children's investigation, the electromagnet serves as a fascinating puzzle. It is a magnet which children can make. Does it really work? Does it attract iron?

How can it be made stronger? How do we know that it is stronger? Does the electromagnet have poles? How can we tell? Can the poles be reversed?

The electromagnet provides endless pathways for individual exploration. It is a self-teaching device: it poses problems, and it furnishes answers.

From the activities suggested, children learn these facts:

When electricity flows through a wire, a magnetic force is set up.

The magnetism around such a wire can be concentrated by winding the wire to form a coil.

The magnetism can be concentrated further by winding the coil on an iron core.

An electromagnet may be made stronger by increasing the number of turns of wire, by increasing the electric current flowing through the wire, or by increasing the size of the core.

An electromagnet is a temporary magnet.

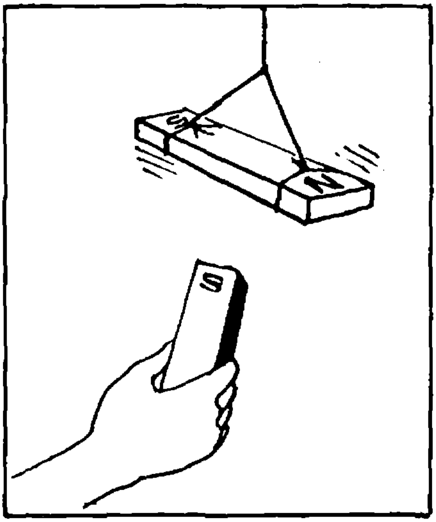
The poles of an electromagnet can be reversed.

1. What can a magnet do?

To understand electromagnets, children should first recall experiences and experiments with magnets in earlier grades.

Hold up a magnet and ask the class, "What is this?" (Most of the children will say that it is a magnet.) Ask, "How can we show that it really is a magnet?" (Some children may say, "See if it picks up iron.") Have volunteers hold the magnet near common objects: paper clips, scissors, iron or steel in chairs and desks. The magnet attracts (or is attracted to) iron and steel objects.

Is there another way of showing that the instrument is a magnet? Try this experiment. Suspend a magnet so that it can swing freely. Notice that it comes to rest in a north-south position. Check the direction with a compass. Label the north and south poles of the magnet.



Some students may suggest bringing two magnets near each other. They find that when they are held in a certain way, the magnets attract each other; when they are reversed, they repel each other. Pupils may recall this law of magnetism: opposite magnetic poles attract each other; similar poles repel each other.

The following chart, developed on the chalkboard as the discussion and exploration proceed, may serve to summarize the findings.

WHAT CAN A MAGNET DO?

Problem	What We Did	What Happened
Can a magnet pick up objects containing iron?	We put the magnet into a pile of clips.	The clips were picked up; most were at the ends (poles) of the magnet.
Can a magnet swing into a north-south position, like a compass needle?	We suspended the magnet from a string. We compared it with a compass.	It lined itself up in a north-south position.
Can a magnet attract or repel another magnet?	We held two magnets near each other in various positions.	In one position the two magnets pulled together. In another position they pushed away from each other. Whenever two north poles or two south poles were together, they pushed away. Whenever a north and a south pole were together, they were attracted to each other.

- *A magnet attracts iron.*
- *A magnet is strongest at its ends (poles).*
- *A magnet can be used as a compass.*
- *Like poles of magnets repel each other: opposite poles attract each other.*

Suggestions for Making Dry Cells Last Longer

Unless precautions are taken, the experiments with electromagnets already mentioned can deplete the school's stock of dry cells quickly. In work with electromagnets, a switch should always be included in the circuit; the switch to be closed for only a few seconds at each trial.

The teacher can conserve cells by cautioning children not to connect a wire directly *across* the terminals of a dry cell. Since electromagnets are wires connected directly across a cell, their use with a cell should be limited. When they are properly connected to dry cells, the current in the circuit is limited somewhat by the cells. (See *Science: Grade 5*, pages 211-213.) However, when a wire is placed directly across the terminals of the dry cell, a very large current flows through the wire and causes the wire to become very hot.

The two wires connected to the dry cell terminals may touch each other at some distance away in the circuit. This contact also results in a short circuit.

During the children's experimentation, the teacher should move among them and call attention to possible short circuits. Good housekeeping also dictates that all dry cells be disconnected at the end of the practice period and when they are stored.

Dry cells used in science fair exhibits will deteriorate rapidly, if excessive current drains and short circuits are not avoided. A good rule to follow to prevent such waste is to place switches in every circuit. For bells and lights, one may use knife switches or, preferably, push-button switches. However, since electromagnets give no audible or visible evidence of being activated, these should be controlled *only by push-button switches*. These switches are automatically in the *off* position when not in use.

2. How can we use electricity to make a magnet?

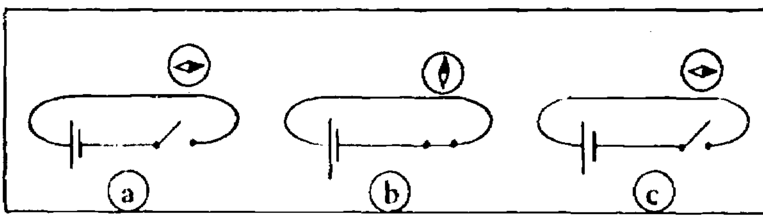
Relate this experiment to the class.

In 1819, Hans Christian Oersted (or'-sted), a Danish scientist, made an important discovery. He was lecturing to a college class about electricity.

He had on the demonstration table a battery, a switch, and electric wire. When he threw the switch so that electricity flowed through the wire, he noticed that the needle of a compass that happened to be near the wire changed its position. When he opened the switch so that the circuit was broken, the needle swung back to its original position.

Ask the children to repeat Oersted's experiment. Distribute dry cells, wire, switches, and compasses. Have them report on what happens. Ask them to make a drawing such as the one in the illustration, showing the wire and the compass needle position when:

a. the switch is open.
b. the switch is closed (electricity is flowing).
c. the switch is open again.

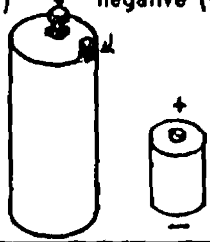
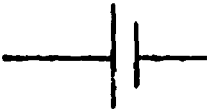
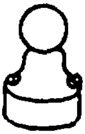
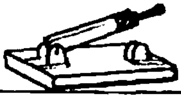


The results of children's experiments may vary, but in most cases they note that the compass needle moves. Ask children why they think the needle moved. Remind them that the needle is a magnet. What can make a compass needle point away from the north pole? Some children may suggest that iron can do this. But the wire is made of copper. What else might influence a compass needle? They may suggest that a nearby compass or magnet influences it. But neither is near. Some children may propose that when electricity flows through a wire, the wire becomes magnetic. Tell them that this was Oersted's discovery, too. The wire becomes an *electromagnet*. This electromagnet can attract another magnet, such as the needle of a compass.

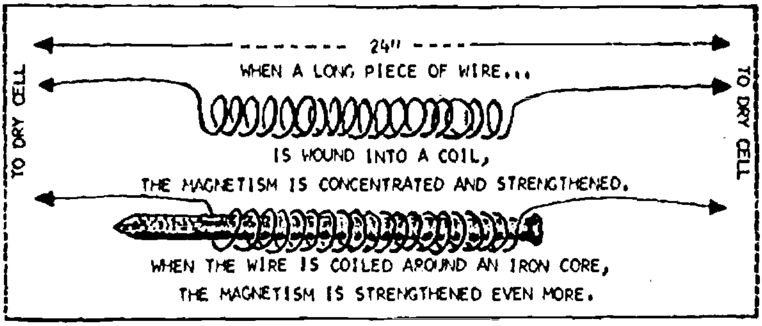
- *When electricity flows through a wire, a magnetic force is set up.*

3. Can an electromagnet attract iron objects?

Children may not readily accept the idea that a wire carrying electricity is truly magnetic. They may want to know if it can really attract iron. The following demonstration may convince them that a wire electromagnet is a real magnet.

	PICTORIAL	SCHEMATIC
dry cell	positive (+) negative (—) 	
wire		
lamp bulb		
lamp bulb in socket		
switch (closed)		
switch (open)		
fuse		

First, it should be pointed out that scientists working with Oersted's discovery later learned that the magnetism in a wire carrying electricity can be strengthened in a number of ways. One way is to wind the wire into a tight coil as shown in the illustration. (To make a coil, wind a wire around a nail, and then remove the nail.) Scientists also found that if wire is coiled around a piece of iron or steel, the magnetism is strengthened even more.



Ask children to test all of these methods with a 24 inch length of wire in a circuit which includes a dry cell and a switch. Have them test each hookup by placing their electromagnets near iron objects such as paper clips. Some children may suggest that their electromagnet is so powerful that they would like to test it on other objects. Encourage them to do this and report their findings. (Do not use it near a watch. It may magnetize the watch and interfere with its working properly.)

- *A wire carrying electricity can attract iron.*
- *The magnetism is strengthened if the wire is wound into a coil around a steel or iron nail.*

4. How can we make an electromagnet stronger?

Ask children to review what they have learned in the previous problem. Thus far they have discovered these facts:

a. that a wire carrying electricity exerts a magnetic force.

b. that the magnetism can be strengthened by winding the wire into a coil around a soft iron core, for example, a nail.

Ask how an electromagnet can be made still stronger. In the discussion that follows children may suggest these ways:

a. winding more turns.
b. using more dry cells.
c. using a larger iron core.
d. using other methods.

Then ask, "How shall we conduct experiments to test these ideas?" Class discussion based on the four points noted here should develop a master plan for experimentation, such as the one indicated on p. 82.

a. How shall we test the strength of the electromagnet? One way is to dip the head of the nail core into a pile of clips, lift it up, and count the clips attached.

b. How can we compare results of different methods? Except where we are testing the effect of the number of turns, use 16 turns of wire as a standard. In all cases use bell wire.

c. The problem of dry cell breakdown may arise. *In all cases the current should be on only for a second or two,* at the time the "clip test" is conducted. A switch is always included in the circuits.

d. Each committee should prepare a report and present it to the class. The report should include a diagram to show the electrical hookup. Graphs are helpful in summarizing results.

- *An electromagnet may be made stronger by increasing the number of turns of wire.*

- *An electromagnet may be made stronger by using two dry cells connected in series instead of one.*

- *An electromagnet may be made stronger by using more nails as a core or by making the core thicker.*

5. Does an electromagnet have poles?

Review the meaning of poles in permanent magnets (see No. 1, p. 75.)

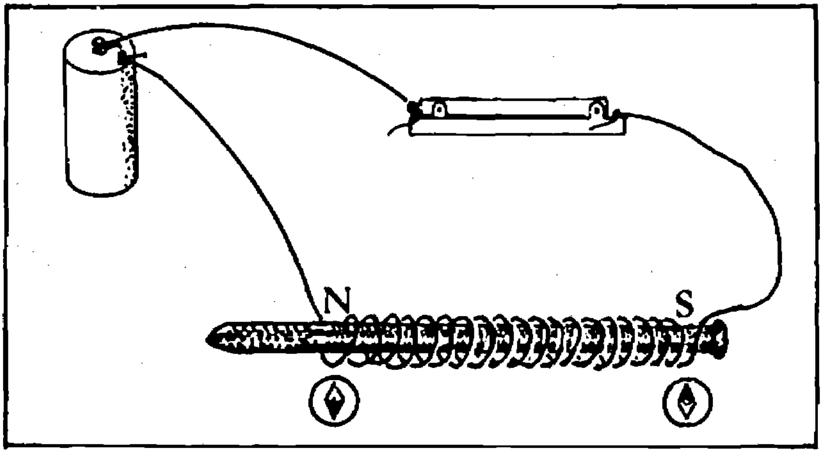
a. A magnet has a north pole and south pole at either of its ends.

b. If it is suspended, a magnet swings into a north-south position, with its north pole toward the north and its south pole toward the south.

c. Opposite poles of magnets attract; similar poles repel.

STRENGTHENING THE ELECTROMAGNET (Master Plan)				
Committee	Method	Directions	Turns, Nails, or Batteries	Clips Picked U
Juan Lee Alice	Increase number of turns.	Hook up electromagnet. Gradually increase number of turns. (Keep other factors constant.)	Turns 2 4 8 16 32	
Jill Rosa Joe	Use more dry cells.	Using 16 turns, connect batteries in series or parallel. (Keep other factors constant.)	Batteries 1 (unconnected) 2 (series) 3 (parallel)	
Miguel Fran Norman	Use larger core (more nails.)	Using 16 turns, gradually increase thickness of core (nails used). (Keep other factors constant.)	Nails 1 2 3	
	Other methods.			

How can we find out if an electromagnet has poles? Children will mak many suggestions, which they should be encouraged to try out. One wa is to place a compass near each end of an electromagnet. What shoul happen? *Ask children to anticipate the results.* If the electromagnet ha poles, one end of the compass needle should point to the end of the electromagnet when the compass is near that end. The other end of the compass needle should point to the other end of the electromagnet when it is brought near it.



Which pole of your electromagnet is the north pole, and which is the south pole? Recalling that opposite poles attract, the north end of the compass needle is attracted to the south end of the electromagnet, and vice versa (the south end of the compass needle is attracted to the north end of the electromagnet).

- *An electromagnet has a north pole and a south pole.*
- *We can test the polarity of an electromagnet with a compass.*

6. Can we change the poles of an electromagnet?

Ask children to check the poles of their electromagnets with a compass. Make a careful diagram of the results on the chalkboard.

Ask these questions: Do you think it is possible to switch the poles of the electromagnet? How would you switch them?

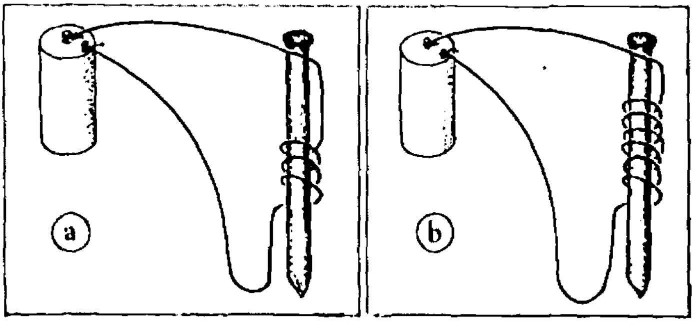
- *We can change the poles of an electromagnet by switching the connections to the dry cell.*

Evaluative Activities

Select the correct answer to each question.

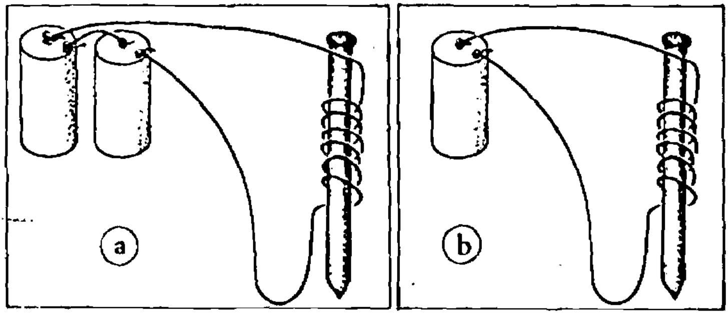
1. Which electromagnet picks up more clips?

(Answer: a.)

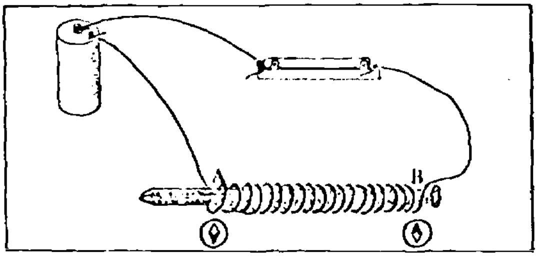


2. Which electromagnet picks up more clips?

(Answer: b.)



3. Shown here is a battery connected to an electromagnet. Tw compasses are nearby.



a. Which end (pole) of the electromagnet is the north end? (Answer: b.)

b. How do you know? (The south end of the compass needle is attracted to it.)

c. Which end (pole) of the electromagnet is the south end? (Answer: a.)

d. How do you know? (The north end of the compass needle is attracted to it.)

USING ELECTROMAGNETS

BACKGROUND FOR THE TEACHER

Electromagnets are used in many devices. In this section we consider two uses of electromagnets: one in magnetic cranes and the other in the telegraph.

The fact that electromagnets are temporary magnets, that is, devices whose magnetism can be turned on and off, makes them useful in cranes for lifting and depositing loads of scrap iron.

Similarly, in the telegraph, the fluctuating nature of the magnetism in an electromagnet makes it possible to transmit messages. In this instance, the current is made to flow by a switch in the sender, which completes the circuit. An electromagnet in the receiver, which may be hundreds of miles away, attracts an iron bar.

When the circuit is broken in the sender, the iron bar in the receiver is no longer attracted, and a spring causes it to return to its original position. A quick on and off movement of the sending switch makes a quick click-clack in the receiving electromagnet and bar, a "dot". A slow on and off switch action makes a slow click-clack in the receiver, a "dash". A code of letters based on dots and dashes makes communication over long distances possible.

APPROACHES AND LEARNINGS FOR THE CHILD

Children find that electromagnets are the essential part of many everyday appliances and toys. They make working models of magnetic cranes and telegraph sets. They make a magnetic merry-go-round and discover how the attraction of iron to a magnet or electromagnet can be used to make this toy turn. They experiment with two magnets and discover how one can make the other spin.

From the activities suggested, children learn the following:

Electromagnets are used in many devices.

The temporary magnetism of an electromagnet makes it useful for lifting and dropping iron loads.

The temporary magnetism of an electromagnet makes it useful for sending messages.

1. Where are electromagnets used?

Ask the children to bring to school and operate toys and home devices with electromagnets run by dry cells (e.g., telephones, walkie-talkies, automobiles, fans, boats, trains).

Where is the electromagnet located, and what does it do? If possible, open the device to see the electromagnet.

NOTE: Children are not to work with motors or other devices requiring house current.

Ask children to conduct a survey and to compile a list of devices that employ electromagnets in the home, school, and community.

- *Electromagnets are found in many everyday appliances and toys.*
- *Electromagnets are used to make motors run, to make bells ring, to make telephones and telegraphs work.*

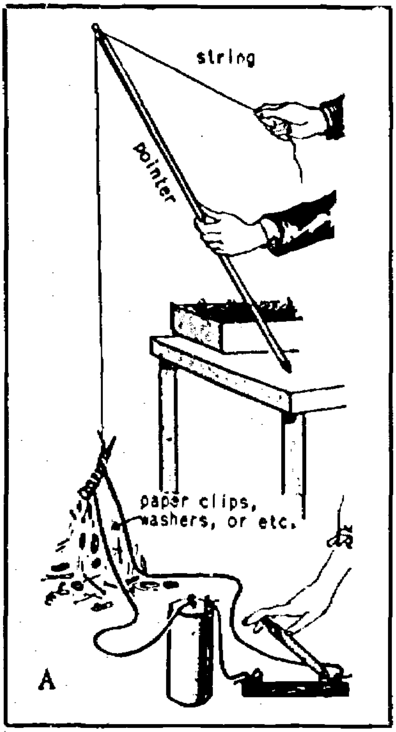
2. How can we make a working model of a magnetic crane?

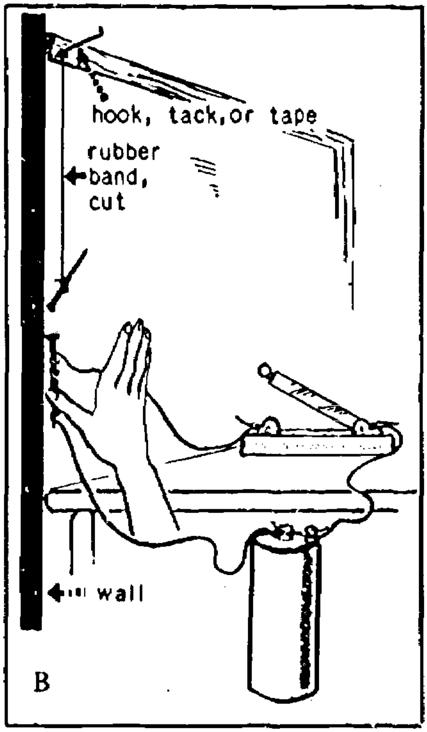
Ask if any children recall seeing magnetic cranes at work in junkyards. Ask how they think these machines work and how a simple working model may be constructed. One device that may be assembled easily is shown in illustration A, opposite. A handful of washers or other objects of iron or steel can be moved from one spot to another with it.

Children may wish to design their own models. They should use their experience in making electromagnets stronger (see pages 80-81) in devising more powerful magnetic cranes.

If possible take a trip to a junkyard to see magnetic cranes in action.

- *The magnetic crane uses an electromagnet.*
- *An electromagnet can be used to pick up and release loads of iron.*





3. How can we use electromagnets to send messages?

Children will recall from various experiences that electromagnets can be used to move iron objects. Ask how this action can be used to signal from some distance away. Try out some of the suggestions made by the children.

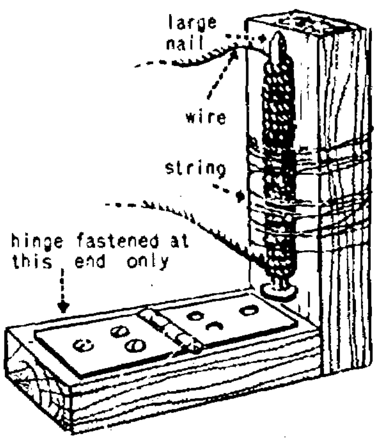
The principle of the telegraph can be shown by using an electromagnet, a rubber band, and a nail (to serve as clapper) in a circuit as shown in illustration B. Experiment to find the proper distance between the two nailheads. Give all the children a chance to work this device. Note that the clicking at the receiving end corresponds to the action of the switch at the sending end.

A report by the children on Morse's invention of the telegraph is suggested.

- *An electromagnet can be switched on and off from a distance.*
- *A telegraph receiver is an electromagnet with a piece of iron which it attracts.*
- *The iron in the receiver produces clicking sounds by means of which messages are received.*

4. How can we make a simple telegraph?

This telegraph sounder is made with an iron hinge that moves easily. Adjust the electromagnet by moving it up and down until the hinge clicks against the nailhead when the circuit is closed. If magnetism persists when the current is off, cover the head of the nail with one layer of scotch tape.



Children can practice the Morse code by using a buzzer, distinguishing between a dot (a short buzz) and a dash (a long buzz).

Place the receiver and the sender as far from each other as practicable.

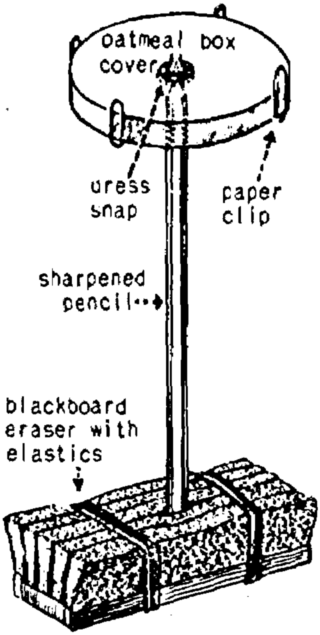
- *An electromagnet can be operated from a distance.*
- *The sender is a switch which opens or closes the circuit.*
- *A telegraph receiver (sounder) contains an electromagnet and a movable piece of iron which the electromagnet attracts.*

• *With a variety of dots and dashes we can make a code to represent all the letters in the alphabet.*

5. How can we make a magnetic merry-go-round?

Children make the toy shown in the illustration. By bringing the magnet close to and away from each clip without actually touching it, the merry-go-round can be made to turn. An electromagnet may also be used.

• *A magnet or an electromagnet can make a toy turn by attracting the iron in it.*



6. How can one magnet make another one spin?

Have the children suspend a bar magnet by means of a light thread looped around the ends of the magnet.

The children are asked to make the suspended magnet rotate with the help of another bar magnet. They find that they can do this by repeatedly bringing the magnet in the hand close to and then away from the suspended one. In some positions, one end of a magnet attracts the other magnet; in other positions, the magnets push each other away. Attraction, repulsion, or both can make the suspended magnet spin.

Also use an electromagnet to make the suspended magnet turn. Children may discover that the suspended magnet can be made to spin without moving the electromagnet. All that is necessary is to turn the current off and on.

- *Magnetism can be used to produce a spinning motion.*

Evaluative Activities

These questions may be useful in evaluating the topic, Using Electromagnets:

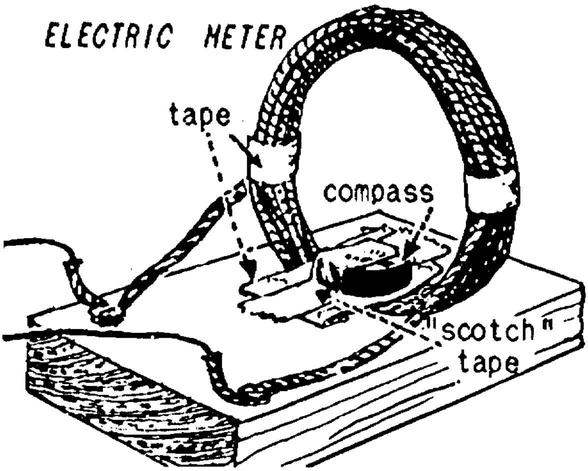
1. Do children "find" electromagnets in everyday devices?
2. Do they report on electromagnets in devices and machines and in the neighborhood?
3. Are they successful in constructing model cranes and model telegraph sounders and receivers?
4. Do they bring to school toys and home devices that use electromagnets (run by dry cells only)?
5. Do they read about Morse's invention?

C. FINDING OUT MORE ABOUT ELECTROMAGNETS

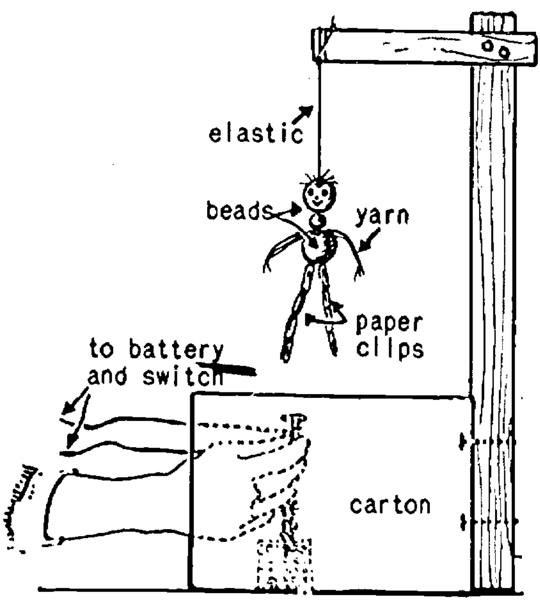
(Enrichment Activities)

The following activities encourage pupils to apply their basic learnings and understandings, develop inventiveness in making electrical things work, and explore further the ideas and interests developed by the preceding activities. The illustrations will be helpful for many of these activities. Children's books on magnetism and electricity will also be useful.

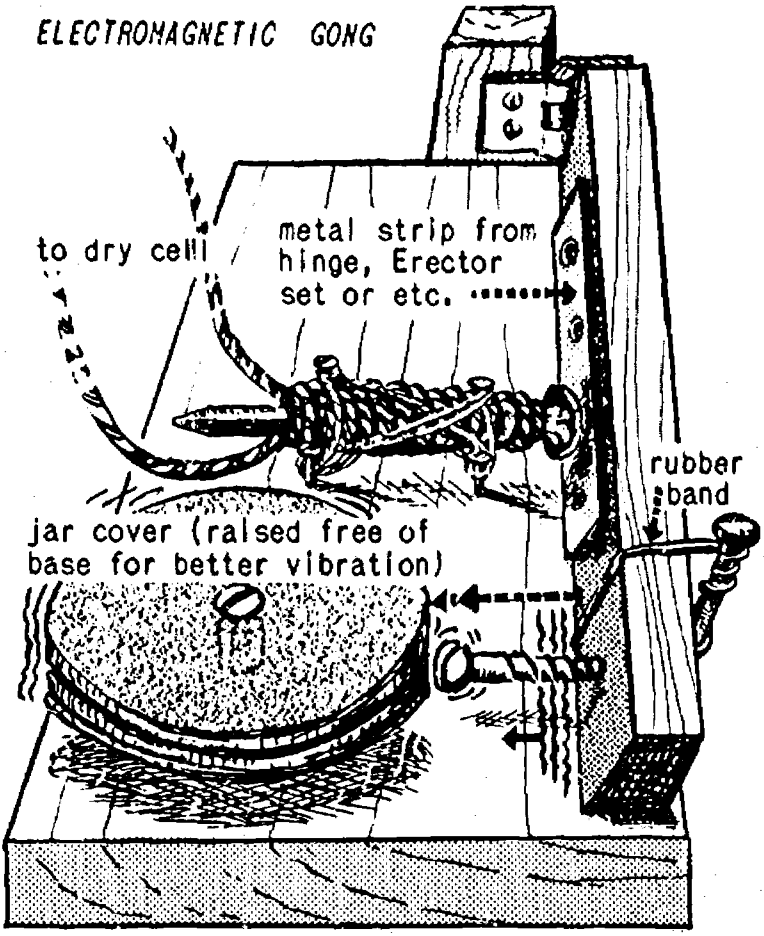
1. Make a simple electric meter to detect electric current. See illustration.



2. Using pulleys of different sizes, make a motor turn things slowly or rapidly.
3. Hook up and use a standard telegraph key and sounder set.
4. Suspend a doll, as in the illustration. It will dance when the hidden electromagnet is turned on and off rapidly.



5. Make a gong, as shown in the illustration.



6. Make a motor from the kits which are sold by hobby stores, department stores, and mail-order houses. Make a motor from plans in a science book or encyclopedia.

7. Hook up a St. Louis Motor (see *Stocked Supply List*) to a dry cell and switch. Try to change speed and/or direction of spin of the

turning electromagnet (a) by varying the number of dry cells used, (b) by switching the connections of the battery to the motor, (c) by changing the position of the bar magnets and (d) by swinging the ends of the bar magnets closer to and farther away from the electromagnet.

8. Explain how a St. Louis Motor works.

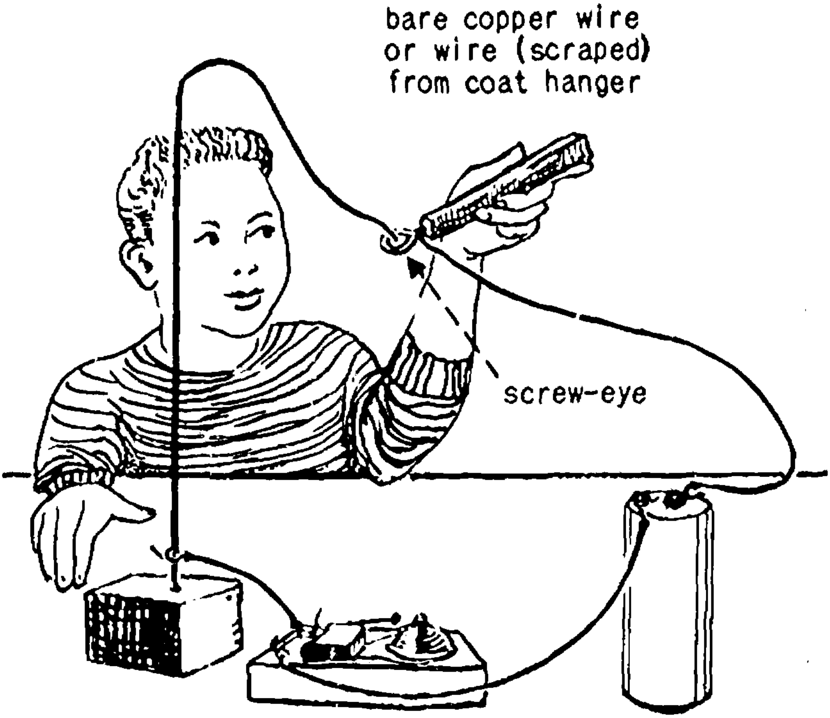
9. Examine a bell or a buzzer. Make a diagram of the electric circuit in it. Explain how it works.

10. Make a working model of a magnetic crane.

11. Make a merry-go-round which is turned by a small motor.

12. Devise an alarm system which rings a bell when the door is opened.

13. Make a "nerve tester". As the loop moves over the stiff wire, if the parts touch because of an unsteady hand, a bell will ring.



BASIC SUPPLY LIST

For Magnets, and Electromagnets

*Indicates quantity for entire class. Other quantities specified are fo individual children or for groups of 2 or 4 children. (Individual work with materials is the most desirable procedure.)

STOCKED SUPPLY LIST

2 Strong bar magnets
1 Compass
1 Knife switch (or push button)
*4 Dry cells
1 Dry cell
1 Miniature lamp socket
1 1.5 Lamp
*1 100′ Coil of bell wire
*1 "D" cell
1 Wire insulation stripper
1 Small screwdriver
2 Boxes of paper clips
*1 6′ Length of string
1 3′ Length of string
1 12″ Ruler
3 11″ Lengths of bell wire
1 24″ Length of bell wire
*1 Buzzer
*1 Bell
*1 Telegraph set
*1 St. Louis Motor
*1 Motor mite
1 Large iron nail
*5 Iron nails
1 Round oatmeal box cover
1 Chalkboard eraser
*1 Wooden pointer with eyelet i end
*1 Iron hinge
1 Pencil

MISCELLANEOUS

Toys that use electromagnets

The Stars and the Universe

A. OUR PLACE IN SPACE

BACKGROUND FOR THE TEACHER

Ask a pupil how many stars he sees on a clear night, and he may answer "hundreds" or "millions". Actually, only about 3000 stars can be seen with the unaided eye from any spot on the earth at one time.

Constellations. People long ago traced pictures of familiar objects, animals, and human beings in the patterns of stars. The American Indians reproduced these forms on buffalo skins. The Ancient Greeks and Romans filled the heavens with their gods and heroes. However, the resemblance of star groups, the constellations, to their namesakes depends to a large degree on the strength of one's imagination.

Earth View of the Stars. The part of the sky that we can see on any night is limited by the fact that we live on the Northern Hemisphere of an opaque globe. People living in the Southern Hemisphere view different stars grouped in constellations that we cannot see in the Northern Hemisphere.

The daily rotation of the earth also changes our view of the sky. The apparent motion of the stars each night is a result of the rotation of the earth. As the earth moves from west to east, the sun, the moon, and the stars appear to move from east to west.

The yearly revolution of the earth around the sun further changes our view of the sky. As the earth moves in its orbit around the sun, a parade of different constellations passes in review. Thus, the spring, summer, fall, and winter skies are different. As a result of the orbiting of the earth, some 9,000 different stars can be seen with the naked eye during the course of a year.

The Universe. What is the place of our solar system in the starry sky? What is the structure of the universe? Where are we located in that structure?

If we turn to the constellations for an answer, we do not get much help. Each of these sky patterns is composed of stars that simply happen to appear to be grouped in a particular part of the sky and suggest some kind of figure to the observer.

Our eyes deceive us in that they give the illusion that all the stars appear to be equally distant from the earth, like lights on a domed ceiling. Careful observations and calculations by astronomers have revealed that the distances of stars in the same group vary greatly. Thus the three-dimensional structure of the universe is not revealed by looking at the stars and constellations because our eyes cannot discern the *depth* of space.

Brightness of Stars. Because our eyes cannot discriminate among the various distances of stars, we assume that their observed brightness is indicative of their real brightness. We do not make this kind of error for nearby sources of light. Thus, we realize that the 100 watt lamp in our room is not as bright as a distant street light, although it appears to be so. We know this because we have walked by a street light and can recall its real brightness. Until space ships travel to the stars, we cannot have such direct experience. The star Sirius, for example, appears brighter than the star Rigel, because the former is much nearer to us. Rigel is about 60 times as far away as Sirius; if both stars were at the same distance from the earth, Rigel would be about 700 times brighter than Sirius.

The apparent brightness of a star depends not only on its distance from the earth, but also on its size and temperature. Stars vary considerably in size with diameters ranging from 10,000 miles to over 450 million miles. Our nearest star, the sun, is about 864,000 miles in diameter.

High and Low Temperature

Stars. If you look carefully at the sky on a clear, dark night you will see that the stars are not all the same color. Some appear to be red, some yellow, some white, and some blue-white. Scientists have discovered that differences in color are due to differences in temperature of the stars. As a piece of metal is heated, it first turns red, then orange, then yellow, then white as its temperature increases. Similarly, the cooler stars are reddish, while the hottest are white to bluish. The surface temperature of the stars ranges from about 4,000° F. to 100,000° F., their interior temperatures rise to millions of degrees.

Distances of Stars. Light travels at the rate of 186,000 miles per second. It traverses approximately six trillion miles in one year. The basic unit used in measuring vast distances in space is the *light year*. One light year is about 6 trillion miles.

The nearest bright star that can be seen with the *naked eye* in the Northern Hemisphere is Sirius, at a distance of 8 light years from the earth. This means it is at a distance of 8 x 6 trillion miles or 48 trillion miles. Polaris, the North Star, is at a distance of 650 light years. As you look at Sirius you see it as it appeared 8 years ago. Polaris's light left it 650 years ago. When you look into the vastness of space, you are looking not only far into distance but also far back into time. If we think of the earth as the center of an imaginary sphere having a diameter of 15 light years we would find within this sphere only 43 stars, including our sun.

Stars in Galaxies. Beginning in the late 1700's astronomers began studying the arrangement of stars in space. Just as a child becomes aware of larger and larger units, such as home, neighborhood, city, state, and so on, a hierarchy in the universe was also discovered: The earth is a member of the solar system; the solar system is an infinitely small part of the *galaxy* called the Milky Way. (*Gala* means milk in Greek.)

The Milky Way (Our Galaxy)

When you gaze into the nighttime sky on a clear summer night, you can see the Milky Way, a white, cloudlike band, arching from horizon to horizon. The nature of the Milky Way was not certain until 1610 when Galileo turned his telescope on it and discovered that it was made of millions of distant stars. Many observations made since with optical (conventional) telescopes and more recently with radio telescopes have revealed the shape and size of the Milky Way.

The Milky Way is an earth view of a portion of a spiral disc in space made up of about 100 billion stars. This huge collection is known as a galaxy. The distance across the disc is about 100,000 light years. The disc is thickest near the center, where it measures about 15,000 light years from top to bottom. Extending from the center of the galaxy are many spiral arms. In one of these spiral arms is our star, the sun, located about 30,000 light years from the center.

From our viewpoint, looking from the inside toward the edge, the galaxy does not look like a spiral disc, but as we have indicated, like a cloudlike band across the sky. To get a better idea of our galaxy's shape, we look at other galaxies in space. Our galaxy of 100 billion stars, is but one of the many galaxies that make up the universe.

Our galaxy is spinning in space like a huge wheel. During its lifetime (believed to be 10 billion years) it has probably made some fifty turns. The closer stars are to the center of the galaxy, the faster they move in their orbits. (This principle also applies to our solar system: Mercury, closest to the sun, moves most rapidly; Pluto, farthest away, moves most slowly.) Our sun, has been estimated to make a turn around the center of our galaxy in 200 million years.

APPROACHES AND LEARNINGS FOR THE CHILD

The purpose of this study is to help the child understand his place in the universe by understanding its structure. One way to establish this orientation is by the use of models. For example, the model of the Big Dipper takes a small sample of the sky and shows its three-dimensional nature. The model of the Milky Way helps the child understand its shape, as well as the place of our solar system in it. Photographs of other galaxies also help the child visualize the one he lives in.

Firsthand observation of stars in the sky is essential in making the topic real for children. Topic B, Observing the Night Sky, which follows, should be taught in conjunction with material in Topic A.

These resources are also useful in this study of the stars:

American Museum, Hayden Planetarium
79 Street and Central Park West
New York, N. Y. 10024

Sky shows. Sky show programs are periodically revised. The teacher must choose the program most closely related to study of the structure of the universe.

Sky information. By dialing 873-0404 teachers, parents, and pupils can secure information concerning visible planets, stars, artificial satellites, and other astronomical bodies or happenings. This daily recording also describes the current sky show.

Special exhibits. The halls surrounding the planetarium dome contain many exhibits related to the exploration and structure of the universe. Among these are meteors from outer space, model rockets and satellites, telescopes, models of the solar system, models of constellations, and a variety of large, illuminated color transparency photographs of galaxies, nebulas, etc.

Brooklyn College Observatory
Brooklyn College
Bedford Avenue and Avenue H
Brooklyn, N. Y. 11210

Write to the Observatory Director to arrange an evening trip for a small group or a class to use the seven-inch Fekker refracting telescope.

Star Maps. Current star maps appear in *Science News* each month. They should be studied.

From the activities suggested, children learn these facts:

The sun is a star.

Stars vary in color, temperature, size, and distance from the earth.

The rotation of the earth on its axis and the revolution of the earth around the sun affect our view of the stars and the constellations.

Constellations are groups of stars that are formed into patterns by the eye.

From different positions in space, the constellations appear different in shape.

The universe is three-dimensional; space has depth.

The solar system is located in a large galaxy of stars called the Milky Way.

The Milky Way is one of thousands of galaxies that form the universe.

1. How can we find the Big Dipper?

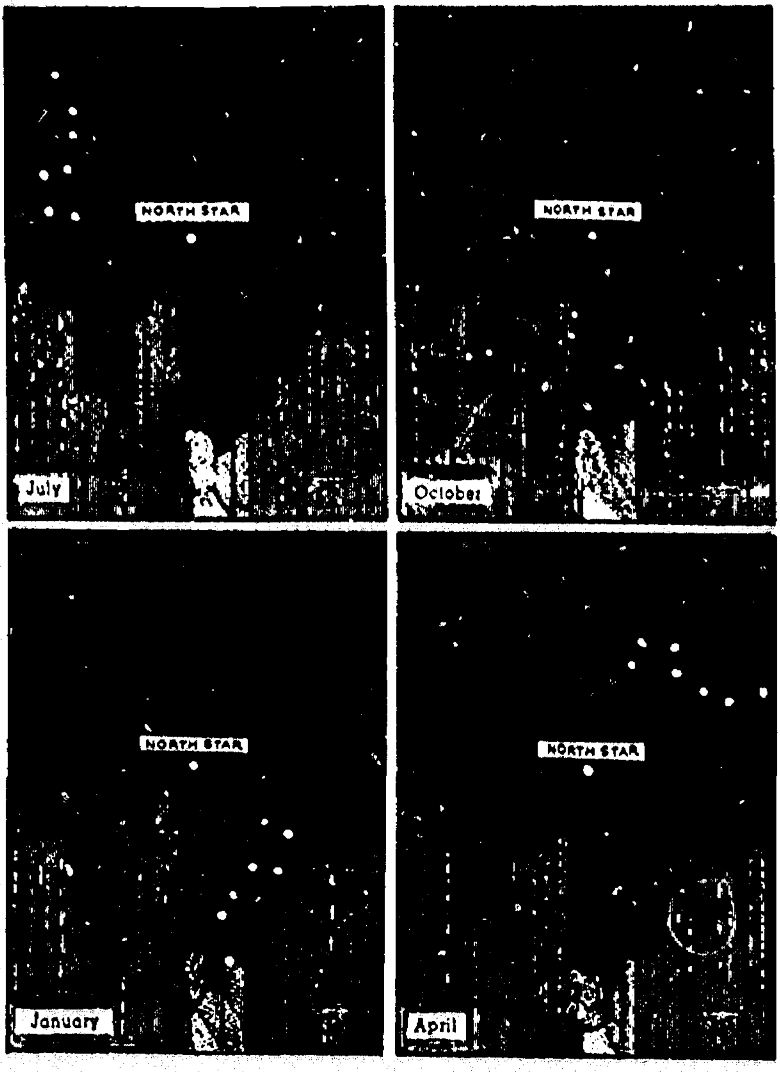
Develop with the class the idea that the Big Dipper gets its name from the fact that some stars outline the form of a dipper. Show by a sketch the similarity between a real dipper and the Big Dipper in the sky.

To help pupils find the Big Dipper in the sky, the teacher might locate it in the sky herself the night before discussing it with the class. She can then describe and perhaps sketch the Big Dipper in relation to the school or a conspicuous feature of the neighborhood, such as a big building, a hill, or a well-known avenue north of the area in which pupils live.

Suggest that the children look for the Big Dipper in the sky after dark.

Ask the children to make a sketch of the Big Dipper as seen in the sky, in relation to a nearby building such as the observer's own house. (If it is impractical to have children find the Big Dipper in the sky at the time of beginning this topic, they may recall a previous viewing and/or postpone the viewing until conditions are favorable.)

- *The Big Dipper gets its name from the pattern of its stars.*
- *The Big Dipper is in the northern sky.*
- *The Big Dipper appears to move from East to West (counterclockwise) in the sky during the night.*
- *The Big Dipper is seen in different positions in the sky in the different seasons (when observed at the same time of night).*



2. How can we make a model of the Big Dipper?

On the day following the previous activity of locating the Big Dipper in the sky, call upon the children to sketch their observations on the chalkboard. Ask them to describe it in their own words: number of stars, shape, location in the sky, similarities or differences in apparent brightness of each star.

Ask children how they would make a model of the Big Dipper. Suggest that such a model might be helpful to astronauts in a space ship. Why? What would we have to know in order to make such a model? Present the following table of distances from the earth of the various stars in the Big Dipper.

Name of Star	*Distance in Light Years*	*Name of Star*	*Distance in Light Years*
Alkaid (al'-kade)	210	Pheeda (fek'-dah)	90
Mizar (my'-zar)	88	Merak (mee'-rack)	78
Alioth (al-ee-ot'h)	68	Dubhe (dubb'-ee)	105
Megrez (meg'-rez)	63		

Review the meaning of light year (Grade 5). A light year is a measure of distance, not time. (See Background for the Teacher, page 97.)

Look at the chart of the distances in light years of each of the seven stars in the Big Dipper.

Ask children several questions about these stars.

a. Which star is closest to the earth?
   (Megrez, which is 63 light years away is closest to the earth.)

b. Which star is farthest from the earth?
   (Alkaid, which is 210 light years away is farthest from the earth.)

c. Which star is half the distance of Alkaid from the earth?
   (Dubhe, which is 105 light years away is half the distance of Alkaid from the earth.)

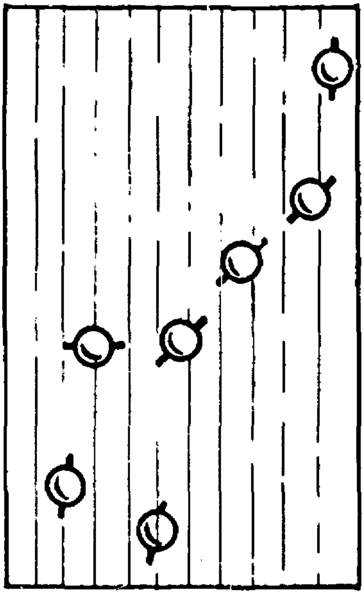
d. If you could travel at the speed of light, how long would it take you to reach Mizar?
   (It would take eighty-eight years.)

e. If Alioth suddenly "blew up" and stopped shining, how many years would it take before we knew it?
   (It would take sixty-eight years.)

f. How does this information about the stars in the Big Dipper change your ideas about its shape?

g. Is the *flat* blackboard diagram correct? (No.)

h. Does it show everything about the shape of the Big Dipper? (No.)



One way of constructing a model and data for this construction is presented here. Using the data, have the children (or a committee) construct a three-dimensional model of the Big Dipper, using seven wooden beads, thread, and a 24" x 12" piece of corrugated cardboard. Tie the thread to the beads and fasten the thread to the cardboard using the dimensions given.

Tell the children to hold their models in different positions. How do these models compare with what you saw in the sky? Hold the demonstration model at a distance of 20 to 30 feet. How does the model differ when observed up close and from far away? Can you see a dipper from any position? Where must you be in the universe to see the Big Dipper? How will the Big Dipper look as we travel through space?

- *The Big Dipper is a group of seven stars in our Milky Way Galaxy.*
- *The Big Dipper is three-dimensional; it is not flat.*
- *The stars in the Big Dipper are at varying distances from the earth.*
- *The apparent shape of a group of stars changes as we look at it from positions in space.*

3. Do all the stars in the sky look the same?

As children observe the night sky, they report their findings. Refer to Topic B, Observing the Night Sky, for specific activities.

- *Some stars appear brighter than others.*
- *Some stars appear to twinkle; some do not. Those near the horizon seem to twinkle more than those overhead.*
- *Stars have different colors.*

4. Why don't we see stars during the day?

With the shades drawn, shine a flashlight in the classroom. Look directly at the light. Take the flashlight out of doors in bright sunlight. When it is lighted, allow the sun to shine directly on the lens. What happens to the light from the flashlight?

Ask the children to look out the window of a lighted room at night to see stars; then tell them to put out the lights and look again. What difference can be n.ted when the sky is observed from a lighted place and from a dark place?

Find photographs or drawings of the sky as viewed from the moon. Can the stars be seen when the sun is out? (Yes.) Why? (There is no atmosphere on the moon to scatter the light of the sun; the sky is always black.)

- *In the sunlight, it is difficult to see stars.*
- *To see stars, it is best to look at the sky from a dark place, away from lights.*
- *Stars shine day and night.*
- *On the moon, and in outer space, one can see stars at all times.*

5. Do stars appear to move during the night?

Ask the children to observe any bright star or group of stars (a constellation) in the southern sky, at hourly intervals, from the same observation point. It will be easier to observe any movement if the star or constellation is sighted over an object like a chimney, a flagpole, or a corner of a building. (See illustration, page 105.)

The hourly observations may be recorded on a chart. Did the star or constellation appear to move? In what direction did it move?

- *Stars appear to move from east to west because the earth turns from west to east.*
- *During the night some stars may be seen rising in the east; others, setting in the west.*

6. Where do stars get their light?

Ask the children to imagine what the sun would look like if one were to travel very far out into space, away from the sun. The sun would appear to become smaller until it looked like any other star.

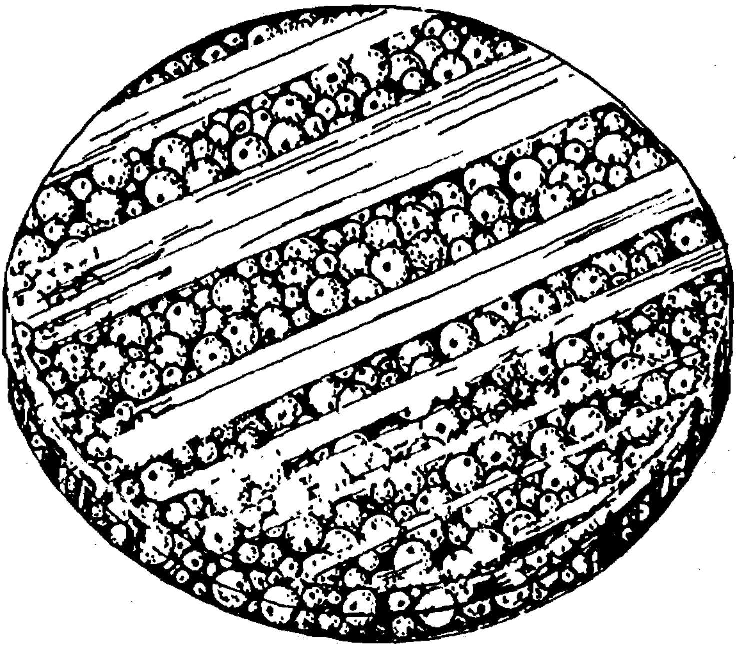
All stars make their own light just as our sun does. The sun produces its heat and light, not by burning, as was formerly thought, but by atomic action which fuses hydrogen atoms, releasing energy in the process. Children may see evidence of atomic activity in the flashes given off by the radium-painted numbers and hands of a watch or clock. Look at the watch in a dark room or closet. After the eyes have become adjusted to the darkness, view the dial through a magnifying glass.

- *The sun is a star.*
- *Stars produce their own light by atomic activity.*

7. Why do we see a Milky Way in the sky?

Ask pupils to recall experiences, particularly in the summer, of seeing a bright band across the sky. In open areas the Milky Way can be seen arching from horizon to horizon.

What is the Milky Way? Observation with field glass or telescope reveals that it is made of billions of stars. Most of the stars in the sky are concentrated in the Milky Way band. What does this band suggest about the arrangement of stars in space? Pupils may speculate and offer various theories to account for this. A model will help students to visualize the band.



Use a clear, flat plastic box (the round kind that holds certain cheese products or candies) to show the wheellike shape of our galaxy. Put glass or wooden beads into the box to represent the stars.

From the top the box has a circular shape. From the side the box appears as a band.

What is our view of this model from the earth? Locate our sun more than halfway between the center and the edge. A large bead may represent the sun and its solar system. How does the Milky Way appear from this viewpoint? Move some beads away from the sun. The pupils may observe that a band of stars is seen circling around the sun (and the earth). Because we see only half of the sky, we see half of a band extending from horizon to horizon.

The Milky Way, then, is an inside view of the galaxy of stars which includes our sun. We see stars outside of the Milky Way band because the galaxy does have depth, but the number of stars outside the band is far fewer than those in it.

- *The Milky Way is an inside view of the great galaxy of stars in which we are situated.*

- *Our galaxy is a wheel-shaped group of billions of stars.*

- *Our sun is one of these billions of stars.*

8. Are there other galaxies in space?

Have the pupils look at photographs of galaxies taken through telescopes. What do these show?

Consider each of these galaxies as a "pancake" in space. They are capable of being seen at different angles. In most galaxies the stars are grouped in spiral arms coming from the center of the "pancake." Some are seen edge-on, as flat discs; some from the top, as round discs. Some are seen at an angle between round and edge-on; these look like ovals.

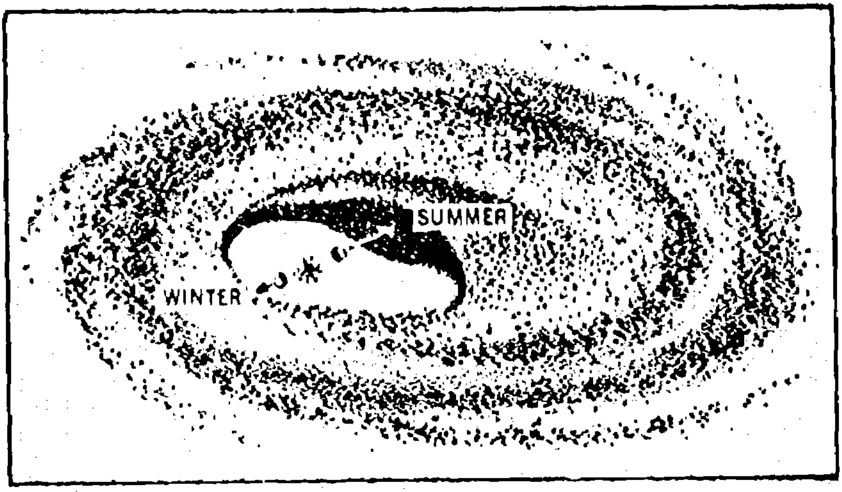
There is evidence that our galaxy also has spiral arms and that it is turning in space.

Thus, viewing other galaxies gives us a better idea of what our galaxy looks like.

Other galaxies are found to be irregular in shape, that is, elliptical or nearly spherical.

- *All the galaxies together make up the entire universe.*

9. Why are there more stars in the summer sky than in the winter sky?



Milky Way

The illustration shows why we see more stars in the summer sky than in the winter sky in the northern hemisphere. (In this illustration, the area around the sun has been cleared to show the cross section we see as the Milky Way.) Our view of our galaxy changes as the earth makes its yearly trip around the sun. During the winter months, we look toward the outer edge of our Milky Way. In late summer, we look toward the center of our galaxy where the stars are denser. The stars can be so great in number as to appear like clouds.

- *The number of stars we see changes as a result of the revolution of the earth about the sun.*
- *Our galaxy has more stars in its center than at the edge.*

10. What is your space address?

This question will help reveal what children have learned from the previous problems. Ask the children to write their address on a sheet of paper. Most children will include their name, house number, street, borough, city, state, and zone number. Discuss with the children what other information might be added if we were taking a trip overseas.

They might suggest that the name of a country would be necessary for further identification.

Ask the children what their address would look like at some future time when they might be writing letters to friends and relatives on the moon, Mars, and Venus. They will see the need for adding Earth to their future address. What is needed to complete our address in space? Children will recall from their previous study that the Solar System, the Milky Way, and the Universe, in this order, are necessary to complete our address in space, as indicated in the following:

John Doe	*Future*
1483 Fifth Street	Solar System
Bronx, N.Y. 10042	Milky Way
United States, Earth	The Universe

- *Earth is a member of the solar system.*
- *Our sun is one of a large group of stars called the Milky Way.*
- *There are many galaxies in the universe.*

Evaluative Activities

Select the best answer possible to complete each of the following statements.

1. As you watch the Big Dipper during the night, it turns counter clockwise in the sky because
   a. it is spinning on its own axis.
   b. it is revolving about the sun.
   c. the earth is rotating from west to east.
   (Answer: c.)

2. A light year is a measure of
   a. distance. b. time. c. neither distance nor time.
   (Answer: a.)

3. Stars get their light from
   a. reflected light of the sun.
   b. burning fuel.
   c. atomic activity. (Answer: c.)

4. The Milky Way is "milky" because
   a. millions of stars are located in that part of the sky.
   b. that part of space is filled with a milky substance.
   c. we are looking at another galaxy beyond our own.

(Answer: a.)

5. From your study of the model of the Big Dipper, it might seei that the universe
   a. is mostly space.
   b. is mostly stars.
   c. is half space and half stars.

(Answer: a.)

6. All the stars of the Big Dipper are
   a. the same distance from the earth.
   b. the same size.
   c. at different distances from the earth.

(Answer: c.)

7. Traveling at the speed of light to the nearest star in the Bi Dipper would take about
   a. 9 days.
   b. 7 months.
   c. 60 years.

(Answer: c.)

8. For an astronaut traveling far out in space, the shape of th Big Dipper
   a. depends on where he views it from.
   b. is fixed and unchanging.
   c. is the same no matter where he views it from.

(Answer: a.)

9. At the same time of night during different seasons we see different constellations in the sky because
   a. the sun is revolving about the center of our galaxy.
   b. the earth is revolving about the sun.
   c. the constellations are revolving about the center of the the universe.

(Answer: b.)

10. Unscramble the lines below to form your return address for the envelope of a letter you are sending to a friend in another galaxy.

Name
Country
Universe
Solar system
House number and street name
Milky Way Galaxy
Borough, state
Earth

Answer:

Name
House number and street name
Borough, state
Country
Earth
Solar system
Milky Way Galaxy
Universe

B. OBSERVING THE NIGHT SKY

(This is an optional section for individual children, groups, or classes with a special interest in astronomy.)

BACKGROUND FOR THE TEACHER

The time tables and charts which are included in problems that follow help in selecting stars and star groups which can be conveniently seen at certain times of the year. However, these studies can also be made at other times and in other places in the sky.

The *twinkling* we observe in stars does not really occur in the stars themselves; it is a distortion produced by the atmosphere around the earth. (If they are seen from the moon which has no atmosphere, stars do not appear to twinkle.) Stars near the horizon or low in the sky appear to twinkle most because light from them passes through more of the earth's atmosphere. On the other hand, stars directly overhead do not twinkle as much.

With a telescope it is possible to determine that many of the objects observed as a single star are actually double stars or multiple stars.

(See Background for the Teacher on pages 95-98.)

APPROACHES AND LEARNINGS FOR THE CHILD

The sky on a clear night is a wonderful sight. It is also a confusing sight at first when one tries to distinguish individual stars and constellations.

The procedure suggested here is to look for and find one star or one star group at a time. Though the stars, their arrangement, and their movements look complicated, they can be understood by successive single steps. Just as we have landmarks on the earth, we have "skymarks" in the heavens. It is not expected or intended that children should learn to know by name the described stars and constellations. This is achieved only by many observations over a long period of time. The technique described here is simple. From the charts and tables, the child obtains the hours at which to look, the direction in which to look, and how far up in the sky to look.

The next day in class, pupils describe what they have seen and make further studies from charts and books.

The purpose of studying this topic is not merely the identification of stars and constellations. These bodies are used to help children understand the universe: its structure and size. It should be taught in conjunction with material in Topic A.

Some pupils may be interested in the myths and legends of ancient civilizations associated with stars and their groupings. These are part of our heritage, and such studies should be encouraged. In addition, the authentic astronomical knowledge of ancient peoples may be the subject of individual reports.

It is recognized that viewing conditions vary considerably according to season, weather, and the part of the city where observations are to be made. The teacher should adapt her plans accordingly.

From the activities suggested, children learn the following.

Stars are different in brightness and in color.

Stars appear in different parts of the sky during the different seasons.

Stars appear to move across the sky during the night.

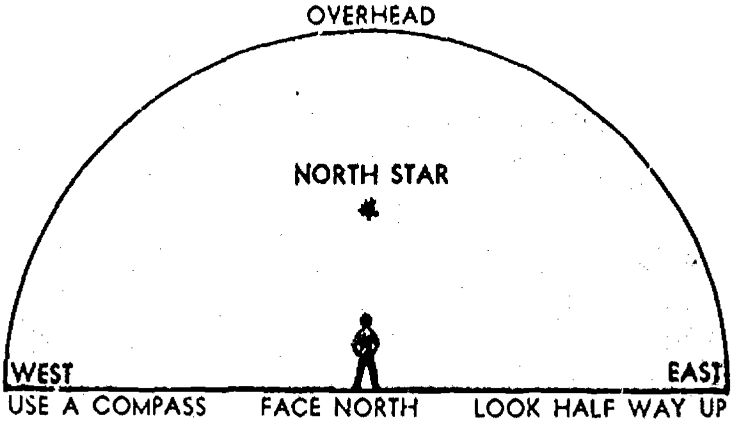
Stars are located at different distances from the earth.

Star patterns, or constellations, help us locate the stars in the sky.

1. How can we find the North Star?

Using an ordinary magnetic compass, let the needle come to rest. Face north as indicated by the needle. With outstretched arm and hand, point to a place halfway between overhead (zenith) and straight ahead (horizon). The star you are pointing at, or the star nearest to where you are pointing, is the North Star. Observe this star from time to time.

Another way of locating the North Star is to find it by using the Big Dipper. Locate the Big Dipper in the sky. The two outside stars of the bowl of the Big Dipper are called the pointer stars because they point to the North Star. If a line is drawn through these stars and extended away from the bottom of the Big Dipper, it will pass through the North Star. The North Star is about five times as far from the pointer stars as the distance between the pointer stars. The North Star is only fairly bright. (See illustration, page 101.)



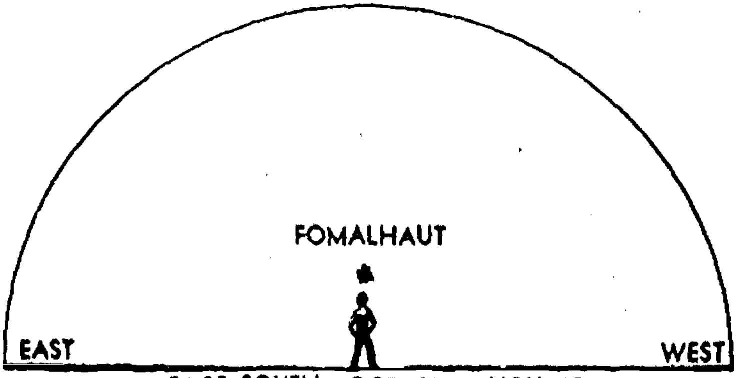
- *The North Star can be found by using a compass or by using the pointer stars of the Big Dipper.*
- *The North Star is always in the North.*

2. How can we find the star Fomalhaut (Foe-mal-oh)? (It appears from October 20 to November 17.)

Use the timetable that follows, not earlier than October 20. Face south and look up about one quarter of the way. Pick out the brightest star in this part of the sky. This is Fomalhaut.

Ask these questions after pupils have had a chance to look, to determine whether they have been successful: What color is Fomalhaut?

(The color is white or bluish white.) Does it twinkle? (It usually do[es] because it is low in the sky.)



Timetable for Fomalhaut*

	Daylight Saving Time				
October	20	10:00 P.M.	November	3	8:00 P.M.
	27	9:30 P.M.		10	7:30 P.M.
				17	7:00 P.M.

• *Fomalhaut is the brightest star seen in the southern sky in the fall.*

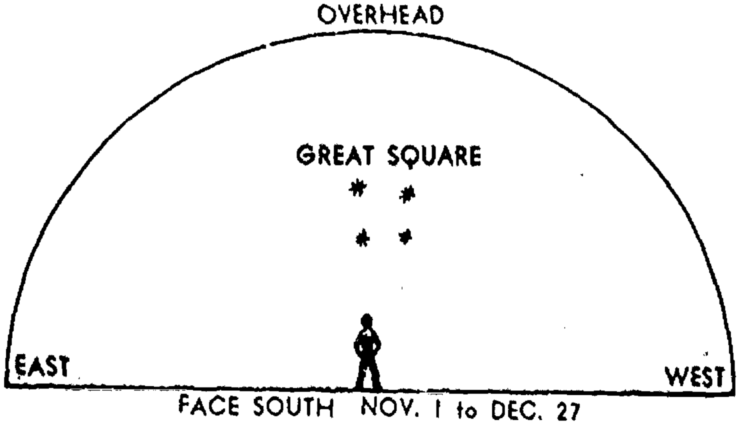
3. How can we find the Great Square of Pegasus in the sky? (I[t] appears from November 1 to December 27.)

The Great Square of Pegasus is the name given to a figure formed b[y] four stars in the sky. Each corner of the square is marked by a star This square (except for the star at the upper left) is part of the constellation Pegasus, the Winged Horse.

Face south and look halfway up. Find four stars which mark out a bi[g] square in the sky.

Ask these questions to determine whether pupils have been successful: Which of the four stars is the faintest? (The one at the lower left i[s] the faintest.) Are there any stars inside the square? (This is unlikely.)

*The approximate date and time for finding the stars in this table and those which follow is given in weekly intervals for the sake of brevity. Time fo[r] intervening dates may be estimated.



Timetable for the Great Square of Pegasus

November	1	9:00 P.M.	December	6	6:30 P.M.
	8	8:30 P.M.		13	6:00 P.M.
	15	8:00 P.M.		20	5:30 P.M.
	22	7:30 P.M.		27	5:00 P.M.
	29	7:00 P.M.			

• *The Great Square is part of the famous constellation Pegasus.*

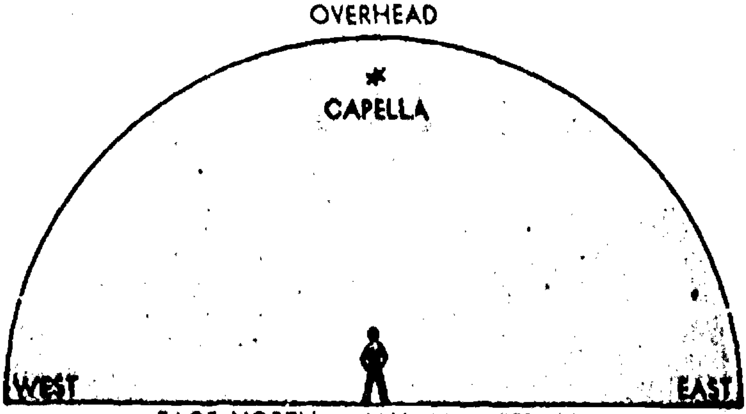
4. How can we find the star Capella? (It appears from January 24 to February 28.)

This is one of the navigation stars used by seamen and airmen in locating their positions. It is the third brightest star that can be seen from New York City. Face north and look high overhead. Find the brightest star in this part of the sky. This star is Capella.

Ask these questions to determine whether pupils were successful: What color is Capella? (The color is yellow, the same as our sun.) Does it twinkle? (This is unlikely since the star is high overhead.)

Timetable for Capella

January	24	9:30 P.M.	February	7	8:00 P.M.
	31	8:30 P.M.		14	7:30 P.M.
				21	7:00 P.M.
				28	6:30 P.M.

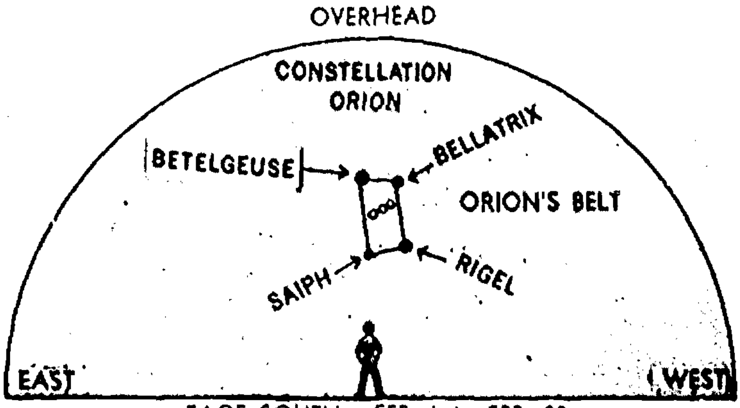


FACE NORTH JAN. 24 to FEB. 28

- *Capella is used by navigators.*
- *A star overhead is not likely to twinkle.*
- *Stars have definite colors.*

5. How can we find Orion (O-ri-on)? (It appears from February 1 to February 22.)

Face south and look halfway up. Find Orion's Belt by picking out three bright stars in a slanting row, as shown in the illustration. Using Orion's Belt as a starting point and referring to star maps, find the rest of the constellation Orion.



FACE SOUTH FEB. 1 to FEB. 22

The red star Betelgeuse (bet-el-jooz), marking Orion's shoulder, is an enormous star.

Diagonally opposite Betelgeuse is a brilliant white double star called Rigel (rye-jel), the brightest star in Orion. Its distance from the earth is more than twice that of Betelgeuse. It is thousands of times brighter than our own sun and is the seventh brightest star in the sky. The white star in the right shoulder of Orion is Bellatrix. If the three stars below Orion's belt which represent Orion's sword are visible, look carefully at the center "star." It appears as a small, misty spot. This is one of the few nebulas that can be seen with the naked eye. It is called the Great Nebula, or M42.

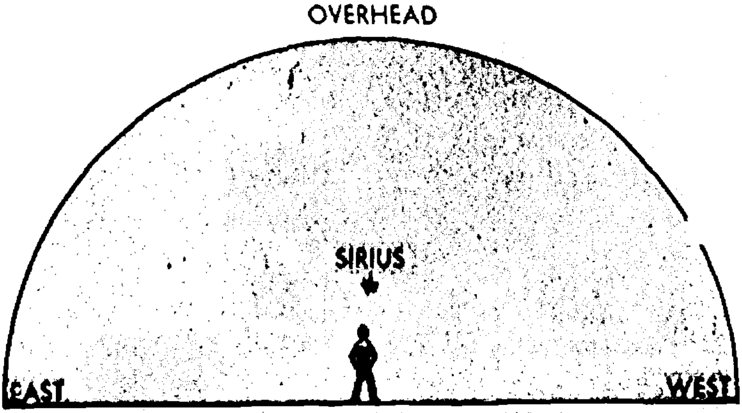
A nebula (neb-yu-luh) is a cloudlike mass of dust. Use binoculars or a telescope, if they are available. M42 appears as a patch of light.

Timetable for Orion	February	1	9:00 P.M.
		8	8:30 P.M.
		15	8:00 P.M.
		22	7:30 P.M.

- *We can use Orion's Belt to find other parts of this constellation.*
- *Orion is a winter constellation.*
- *One of the "stars" in Orion's Belt is a nebula, a cloudlike mass of dust.*

6. How can we find the Dog Star, Sirius (seer-ee-uss)? (It appears from February 16 to February 28.)

Face south and look up about one third of the way. Pick out the brightest star in this position. This is Sirius, the brightest of all stars.



FACE SOUTH FEB. 16 to FEB. 28

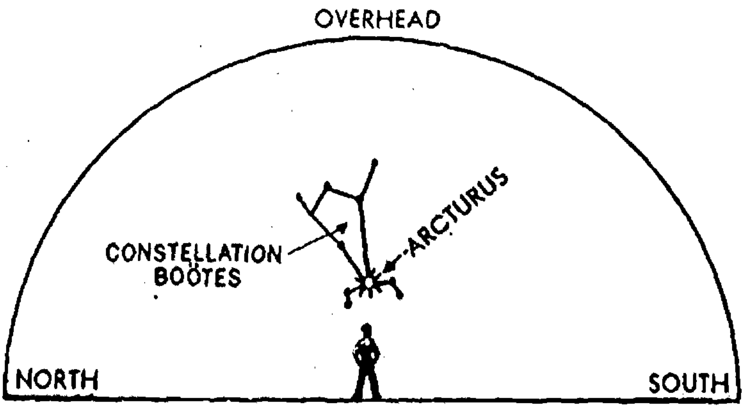
Ask these questions after pupils have observed, to determine whether they have been successful: What color is Sirius? (It is bluish.) Does it twinkle? (This is likely since it is low in the sky.)

Timetable for Sirius	February	16	9:00 P.M.
		23	8:30 P.M.
		28	8:12 P.M.

- *Sirius appears to be the brightest of all the stars in the sky.*
- *Sirius is a winter star.*

7. How can we find Gemini (jem-in-ee), the Twins? (They appear from March 1 to March 29.)

Select a date and time from the table that follows. Face south. Look up very high, not quite directly overhead. Pick out two stars that seem to form a pair. They are bright, but not as bright as some other stars in other parts of the sky. They seem to be as far apart as the distance eight full moons would cover. The two principal stars of the constellation are the heavenly Twins, Castor and Pollux. Pollux is the farther south of the two.



FACE EAST MARCH 20 to APRIL 17

Ask this question after pupils have looked, to determine whether they have been successful: Which one is brighter? (Pollux, the lower one, is brighter.)

The space project Gemini is so named because two astronauts manned the spaceship.

Timetable for the Heavenly Twins (Gemini)

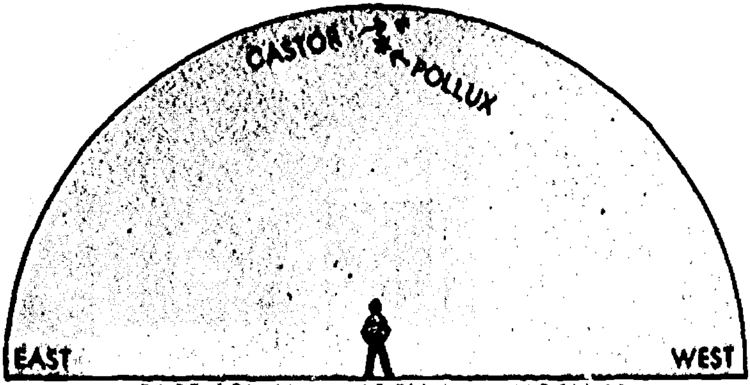
March	1	9:00 P.M.	March	15	8:00 P.M.
	8	8:30 P.M.		22	7:30 P.M.
				29	7:00 P.M.

- *Stars can be told apart by their brightness and color, as well as by their position.*

8. How can we find the star Arcturus (ark-too-russ)? (It appears from March 20 to April 17.)

Arcturus is a bright star about 25 times greater in diameter than the sun. It is in the constellation Boötes (boh-oh-tez), the Herdsman. Boötes is a figure of 5 stars resembling a kite. At the end of the kite's tail is the golden-orange star, Arcturus.

Select a date from the table that follows. Face east and look up a little less than one third of the distance between the horizon and the zenith (the point directly overhead). Pick out the brightest star in that region. It is Arcturus.



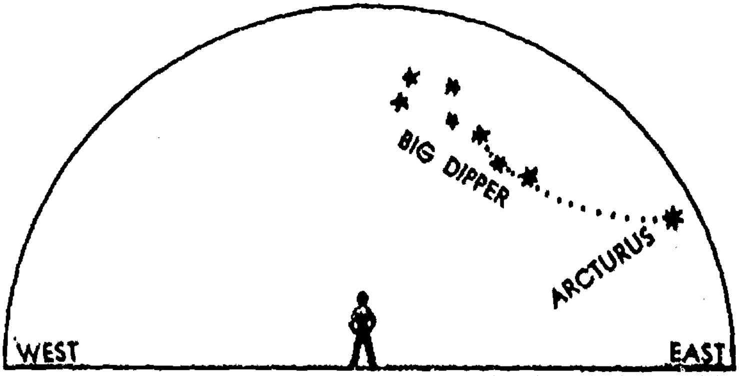
FACE SOUTH MARCH 1 to MARCH 29

Timetable for Arcturus

March	20	9:00 P.M.	April	3	8:00 P.M.
	27	8:30 P.M.		10	7:30 P.M.
				17	7:00 P.M.

Another way to find Arcturus in the sky is to use the Big Dipper as a guide. With the eye, follow the smooth curve made by the stars in the *handle* of the Big Dipper. Extend this curve along the length of the Big Dipper, thus leading the eye to Arcturus.

OVERHEAD



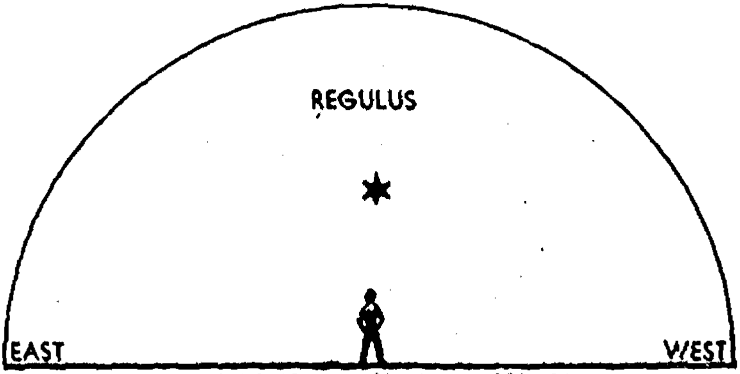
ANOTHER WAY TO FIND ARCTURUS   MARCH THROUGH JUNE

- *Although Arcturus is 25 times as large as the sun, it appears smaller because it is so much farther (36 light years) away.*
- *Arcturus makes its appearance in our skies in the spring.*

9. How can we find the star Regulus? (It appears from April 9 to April 30.)

Face south. Look up three quarters of the way toward the zenith. Find the brightest star in this part of the sky. This star is Regulus. (It is in the constellation of Leo, the Lion.)

OVERHEAD



FACE SOUTH   APRIL 9 to APRIL 30

Ask this question after pupils have looked, to determine whether they have been successful: What color is Regulus? (It is bluish-white.) Children will recognize Regulus easily as the bright star at the end of the "sickle" which forms the head and forepart of the lion.

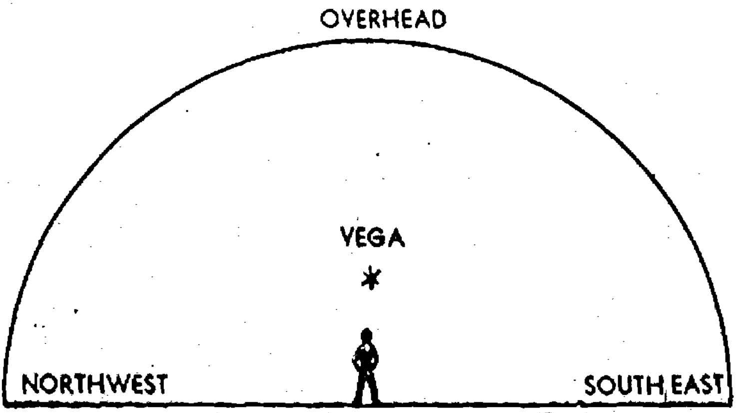
Timetable for Regulus

April	9	9:00 P.M.	April	23	8:00 P.M.
	16	8:30 P.M.		30	7:30 P.M.

• *Regulus is seen in our skies in the spring.*

10. How can we find the star Vega (Vee'-ga)? (It appears from May 15 to June 12.)

Vega is a bright, bluish-white star in the constellation Lyra (Lie'-rah). To find Vega, select a date from the table that follows. Face northeast and look up about a third of the distance between the horizon and the zenith (the point directly overhead). The bright blue star is Vega.



FACE NORTHEAST MAY 15 to JUNE 12

Ask these questions after pupils have had a chance to look, to determine whether they have been successful: What color is it? (It is bluish-white.) Does it twinkle? (It usually does, since it is low in the sky.)

Timetable for Vega

May	15	10:30 P.M.	June	5	9:00 P.M.
	22	10:00 P.M.		12	8:30 P.M.
	29	9:30 P.M.			

• *Vega appears in our skies with the approach of summer.*

Evaluative Activities

These questions will help the teacher to judge the impact of Topic B, Observing the Night Sky, on the class.

1. Do the children actually look at the night sky and report on their observations?
2. Do the children report on current happenings in the sky, such as: eclipses, comets, aurora borealis?
3. Do children find the various constellations at the different seasons of the year?
4. Are the children able to distinguish between planets and stars?
5. Are children aware of the differences in brightness and color of the different stars?
6. Do the children visit the planetarium on their own time?
7. Do the children show evidence of using field glasses and telescopes to observe the stars?
8. Is the children's interest in the stars reflected in the projects they prepare for science fairs?
9. Do the children read about astronomy in newspapers, magazines, and books?

C. FINDING OUT MORE ABOUT STARS AND THE UNIVERSE

(Enrichment Activities)

This section lists some suggestions for special projects for interested students. The children should be encouraged to present their findings to the class and to use them in school exhibits and science fairs. Refer interested students to the books listed in the Bibliography.

1. Construct a four-power Galilean telescope. Refer to pages 122-129, *Exploring Light and Color* by Charles D. Neal. (See Bibliography.)

2. Develop a glossary of astronomical terms. You may wish to include one or more of the following terms:

Binary Stars	Star
Zenith	Galaxy
Horizon	Nebulae
Nova	Variable Stars
Ecliptic	Light Year
Zodiacal Constellations	Constellation
Asterism	Pulsars

3. For a long time scientists have thought about how the universe might have come into being and have developed several theories. Investigate and report on the following theories about the universe:

a. Big bang b. Steady-state c. Pulsating universe

4. Report on the life and contributions to astronomy of one of the following men: Aristotle, Eratosthenes, Aristarchus, Al-Sufi, Hipparchus, Claudius Ptolemy, Nicolaus Copernicus, Tycho Brahe, Johannes Kepler, Galileo Galilei, Isaac Newton, William Hershel, Benjamin Banneker, Albert Einstein, Bernard Lovell, Karl Jansky, and Grote Reber.

5. Use the ray box and optics kit which are on the *Stocked Supply List* to demonstrate how a curved (convex) mirror can be used to gather and focus light as in a reflecting telescope.

6. Build a prism type spectroscope. Use it to demonstrate how the light from an incandescent object can be analyzed and the nature of its composition determined. For instructions on building and using such a spectroscope see pages 158-164, *Exploring Light and Color*, by Charles D. Neal. (See Bibliography.)

7. Try photographing star trails, which are streaks of light showing the *apparent* star movement resulting from the earth's rotation. Set a camera pointing toward the North Star on a clear, moonless night. Open the diaphragm to maximum opening. Focus for infinity. Using a time exposure shutter, a tripod, and film (ASA 400) arrange an exposure of about one hour. The camera must be located where house or street lights will not fog the film. The longer the exposure, the longer will be the star trails. The developed picture will show concentric arcs of circles around the North Star.

BASIC SUPPLY LIST

The Stars and the Universe

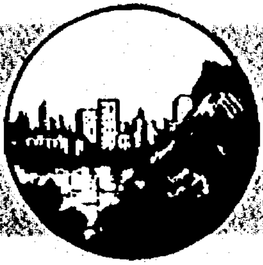
*Indicates quantity for entire class. Other quantities specified are for individual children or for groups of 2 or 4 children. (Individual work with materials is the most desirable procedure.)

STOCKED SUPPLY LIST

1 Compass
*1 Magnifying glass
*1 Star chart, northern skies
*1 Flashlight
1 Pair of scissors
1 Spool black thread
*7 ½″ Wooden beads with hole for stringing
*100 ½″ Wooden beads

MISCELLANEOUS

1 Piece of corrugated cardboard, 24″ x 12″
1 Clear, flat plastic box (circular in shape)
1 Watch or clock with radium dial



Molecules and Atoms

A. EVERYTHING IS MADE OF MOLECULES

BACKGROUND FOR THE TEACHER

Take a small amount of a common substance, e.g., a glassful of water. If we pour out half of it, the half which is left is still water. If we pour out half of the remainder and keep repeating the process, would we ever reach the limit at which further reduction destroys the water? Or is there no limit? There is a limit, and this limit is reached when only one molecule of water is left in the glass.

In other words, water is made of separate, distinct particles: molecules. In a glass of water there are billions of water molecules with much empty space around them.

The theory that all substances are made of molecules is fundamental in the study of science. It holds true for liquids, gases, and solids. A mixture of gases, such as air, is made of molecules separated by wide spaces. In a liquid, such as water, the spaces are smaller. Even an object as solid as a bar of iron is made of separate molecules, but with spaces smaller than those in liquids or gases.

Molecules are in constant motion. Sometimes molecules "escape" from their surroundings. A street puddle dries up because its water molecules have bounced into the air and disappeared as water vapor. When a lump of sugar dissolves in a cup of coffee, the molecules of sugar break away from the lump and move in among the molecules of the liquid.

Another characteristic of molecules accounts for the fact that substances do not fly apart. A strong force of attraction exists between molecules. In a solid this force is sufficient to prevent an object from changing shape easily. In liquids, the molecules are freer to move; consequently, liquids take the shape of the containers they are in. Gas molecules are held together so weakly that they can move far apart quickly. Anyone who has opened a bottle of ammonia water knows how rapidly the odor of ammonia spreads. Heating a substance makes its molecules move greater distances. As a consequence, most substances—solids, liquids, and gases—expand when heated. Cooling has the reverse effect.

Molecules of ammonia differ from molecules of water. In turn, these differ from molecules of other substances. But one water molecule is the same as another water molecule, and one ammonia molecule is the same as another ammonia molecule.

APPROACHES AND LEARNINGS FOR THE CHILD

A study of molecules and atoms helps children to understand the nature of matter. It helps them understand that the large-scale events which they witness have their causes in the behavior of tiny particles.

In this study, we do not attempt to give the proof which convinced scientists that atoms and molecules exist. Instead, we ask children to apply this theory to explain certain observations which they can make.

The activities given here are arranged to introduce children to the world of molecules and atoms. It is hoped that because of the insights which are developed, children will "see" molecules and atoms everywhere; that they will try to explain everyday phenomena on the basis of the activities of these tiny particles; that the words "molecule" and "atom" will become part of their everyday language.

From the activities suggested, children learn these facts:

All substances are made of molecules.

Molecules are very small.

The smallest amount of a substance is a molecule.

There is space between molecules of every substance.

Molecules are far apart in gases, closer together in liquids, closest in solids.

Molecules are always moving.

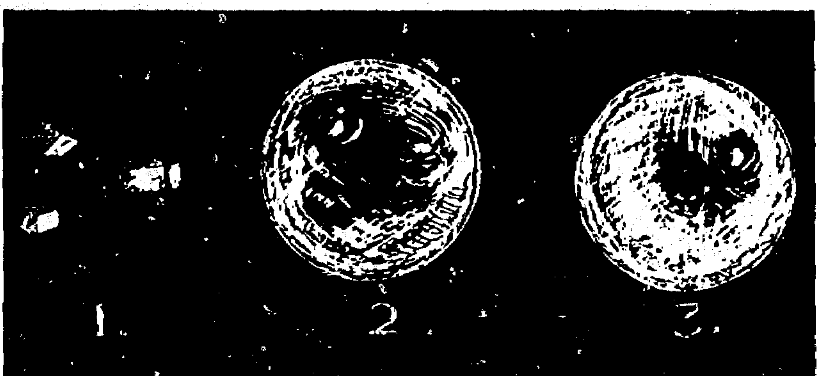
Molecules attract each other.

1. How can we break a lump of sugar into its tiniest pieces?

Children may suggest using stones, hammers, and other implements to break the lump of sugar into smaller and smaller pieces. Allow them to try some of these methods, and to inspect on a background of dark paper the sugar fragments produced in this way. A magnifying glass will reveal that many of the fragments are still recognizable particles. The students may suggest other methods for crushing these grains into smaller fragments.

When the sugar has been reduced to a fine powder, ask the children if there is any way of making the specks so small that they become invisible. Some children may suggest the idea of adding a few drops of water to these fine grains of sugar. Have them do this in a glass dish set on a dark background. In a very short time the sugar disappears. What has happened to it?

The sugar has separated into very tiny bits which are now scattered throughout the water. These bits are so small that the most powerful microscopes, even those magnifying 100,000 times, do not reveal them. These bits are *molecules* of sugar.



Sugar disappears and dissolves in a drop of water

Develop the idea that all substances are made of tiny particles called molecules. Thus salt, water, air, wood, iron, etc. are made of molecules.

- *When sugar is mixed with water, it breaks up into very tiny pieces.*
- *The tiniest bits of sugar we can get are called molecules of sugar.*
- *Sugar molecules are very small.*
- *All substances are made of molecules.*

2. How many molecules are there in a spoonful of sugar?

Stir a level teaspoon of sugar into a glass of clear water. Children observe the sugar crystals disappear. Is the sugar still there? How can we tell?

One way to detect sugar is to taste the water. Dip clean toothpicks, one for each child, into the glass for the children to taste the water.

Discussion should reveal that although only a small drop of water was removed by each toothpick, each of these drops contained sugar molecules. There were enough molecules for every child to taste, yet almost all of the water was left in the glass.

How many children can dip a toothpick into the glass and taste the sugar? Many thousands, perhaps 10,000 children might do this. This means that there are at least 10,000 sugar molecules in the glass of water. Actually, there are many billions of molecules. This experience and the previous experience and discussion introduce children to the concept that there are a large number of molecules in a small amount of material.

From this concept follows the concept that molecules are very small.

- *There are many molecules in a spoonful of sugar.*
- *The molecules of sugar are very small.*

3. What is the smallest bit of water you can get?

Display a glassful of water. How can we get the tiniest possible bit of water from it?

Divide the water in two parts by pouring half of it into an empty glass. Continue this process until it is no longer feasible. How can we further divide the water which clings to the last glass in the series?

Children know that placing the glass on a warm radiator or in the sunlight will cause it to dry. Try one of these methods. What happens to the water?

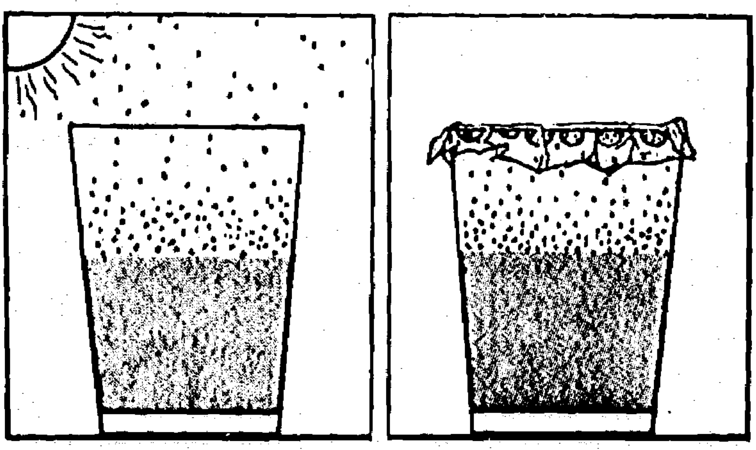
In the process of evaporation, water molecules leave the drops and enter the air to become invisible water vapor. Water vapor, then, consists of individual water molecules which are scattered among air molecules.

- *The smallest bit of water is a molecule of water.*
- *When water evaporates, water molecules move into the air.*

4. How can we collect water molecules from the air?

Partly fill a jar with warm water. Cover the jar with plastic wrap. Allow it to stand. After some time, children will observe conspicuous drops which form on the plastic wrap. Ask the children to tell what they think happened *in terms of molecules of water*. Discussion may develop in this manner:

First, water molecules from the water in the glass scattered into the air above. This is the essence of *evaporation.*



Second, water molecules in the air of the jar collected and settled as visible drops on the plastic wrap. This is the essence of *condensation.*

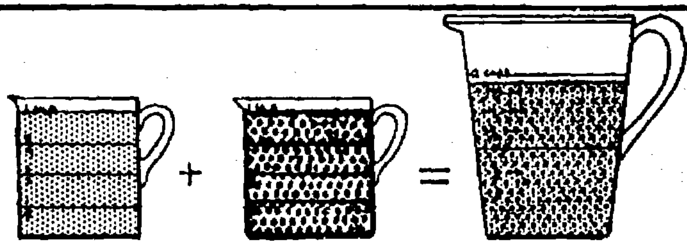
- *We can collect water molecules from the air.*
- *When many water molecules collect in one spot they form visible drops.*

5. Are there spaces between molecules?

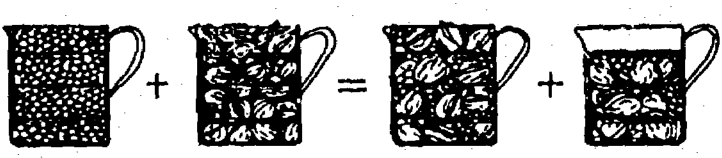
If there are spaces between molecules, what happens if you mix eight fluid ounces of water with eight fluid ounces of alcohol? Children theorize that the molecules of alcohol slip into the spaces between the water molecules. If this happens, how much space does the combined alcohol-water mixture occupy? Is it less than or exactly 16 fluid ounces?

Scientists have found that in this case eight plus eight does not quite equal sixteen. (The experiment is too delicate to perform satisfactorily in the elementary school classroom.) The alcohol and water together do take up a little less than 16 fluid ounces.

A rough way of visualizing this is to mix a cupful of dried peas with a cupful of walnuts. Shake the mixture vigorously. Then pour the mixture back into cups. It now fills less than two cups.



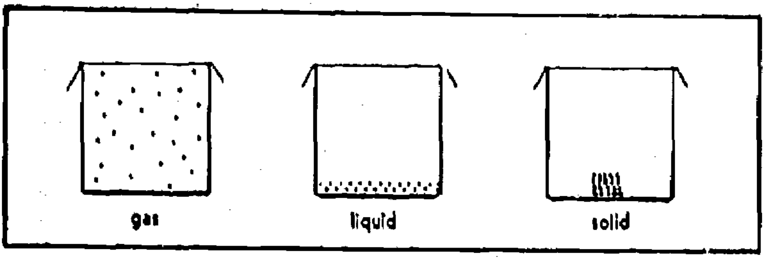
One cup of alcohol + one cup of water = less than two cups when mixed.



One cup of dried peas + one cup of walnuts -- less than two cups when mixed.

It is difficult to accept the idea that a substance such as water has spaces between its molecules. Make clear to the children that there is literally nothing between the molecules, neither air nor any other substance.

The molecules of *all* substances are separated by space. In general, in gases, such as air, the molecules are far apart. In *liquids*, such as water and alcohol, the molecules are closer together. In *solids,* such as iron, the molecules are still closer.



- *There is space between the molecules of all substances.*
- *Molecules are far apart in gases, closer in liquids, still closer in solids.*

6. Can you smell molecules?

Children may be amused with this question, but discussion and observation of the experiment described below will develop the idea that the detection of odors results from the sensitivity of nerve endings in the nose to molecules of the substance which is smelled.

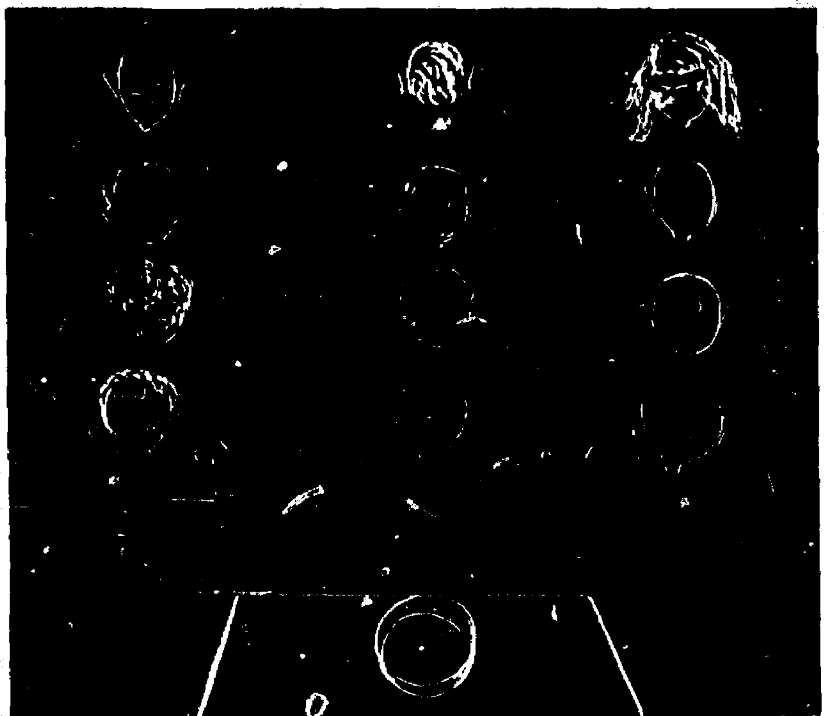
Children may be encouraged to name some of the odors which they can detect, such as those of perfume, gasoline, onions, and flowers. How does the odor of something like perfume get to our nostrils?

Close the windows and doors of the classroom to prevent drafts and other air currents from influencing the demonstration. Pour a small amount of perfume into a dish at the front of the room. Ask the children to raise their hands as they detect its odor. (See illustration on page 132.)

Inspection of the dish will show that the perfume is evaporating. The "odor," apparently, is the perfume itself. How does it reach the nostrils?

Children will recall that in the evaporation of water molecules leave the liquid water and enter the air. The same process occurs with perfume. Billions of perfume molecules enter the air, scatter, and eventually reach the nostrils of everyone in the room.

- *When perfume evaporates, its molecules are scattered in the air.*
- *When we detect the odor of a substance, it is because its molecules enter our nostrils with the air we breathe.*



If molecules of perfume were visible, this is how they might scatter.

7. How do molecules move around?

The previous problem raises the question of exactly how molecules of perfume get from one place to another. Scientists have found that the *molecules of all substances are in constant motion.* A molecule of perfume in the air travels in a straight line until it hits another molecule. Then it bounces off in a new direction.

Why didn't all the children in the perfume-smelling experiment raise their hands at the same time? Molecules from the open dish of perfume moved into the air. The molecules kept on traveling, reaching nose after nose. It took longer for the perfume molecules to reach the noses that were farther away.

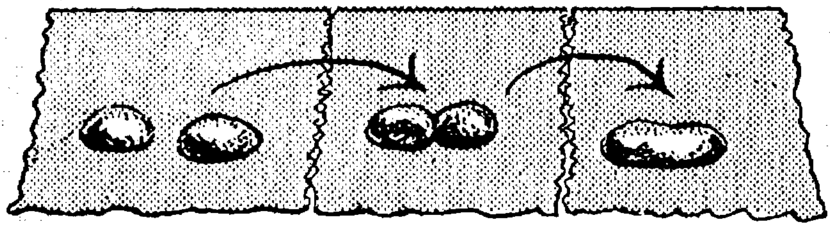
Even though the perfume molecules were finally mixed with a whole roomful of air molecules, the children could still detect them.

Have children sniff the air about a foot above the dish. Why is the odor much stronger? A sniff of air near the dish contains many more perfume molecules than a sniff of air elsewhere in the room.

- *Molecules are always moving.*
- *Molecules travel in all directions.*

8. What holds things together?

In Problem 5, children learn that there are spaces between the molecules of all substances. In Problem 7, children learn that molecules are always moving. Why doesn't everything fly apart? The answer is brief: molecules attract each other.



To see molecular attraction, children sprinkle several drops of water on a clean sheet of wax paper. With a small strip of wax paper, they push one of the drops until it touches another one. Children will observe that the two drops "run together" to form a single drop. Why? Each drop of water is a clump of millions of molecules. When the two clumps are close enough, the attraction of the molecules in them is strong enough to pull them together.

The same experiment may be tried with two drops of oil on wax paper or with two drops of oil floating on water.

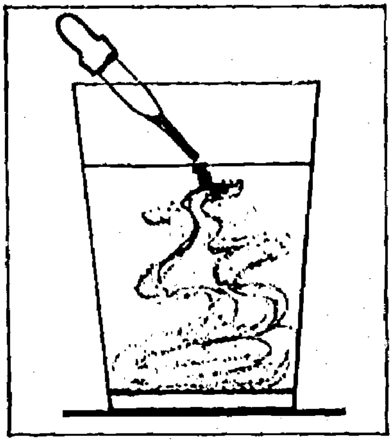
The attraction that molecules have for each other holds things together—sidewalks, steel girders, baseball bats, wire, thread. A strong material is one in which the molecules have a strong pull on each other.

Unlike molecules can also attract each other. Pencil markings (graphite) are attracted to paper. Otherwise, writing would fall off the paper.

- *Molecules attract each other.*
- *The pull of molecules on each other holds things together.*

9. Can we see molecules move?

In Problem 6 we smelled molecules. Can we see molecules move? Not directly, since most molecules are too small to be seen, even with the most powerful electron microscopes. We can, however, use our eyes to find *evidence* of the motion of molecules.

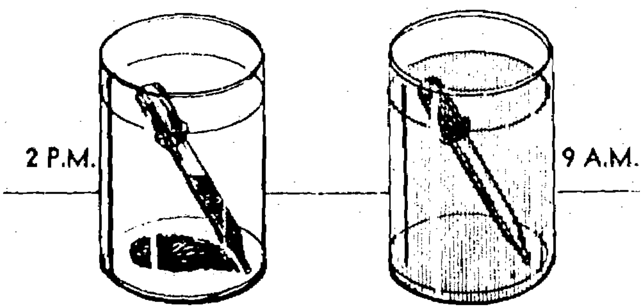


For this experiment, the molecules in ink will be used. Allow a glass of water (which is at room temperature) to stand until the water is perfectly still. With an eye dropper add a drop of ink to the surface of the water.

Watch the drop. What is seen? The drop appears to scatter and disappear in the glass of water. Why?

The drop of ink separates into smaller and smaller droplets that spread through the water. This happens because the molecules of ink are constantly moving. The ink molecules scatter through the water. This scattering of molecules is known as *diffusion*.

Some children may say that the ink fell down in the water. How could we find out if the scattering of ink is indeed due to falling, rather than diffusion?



Ink molecules scatter and mix with water.

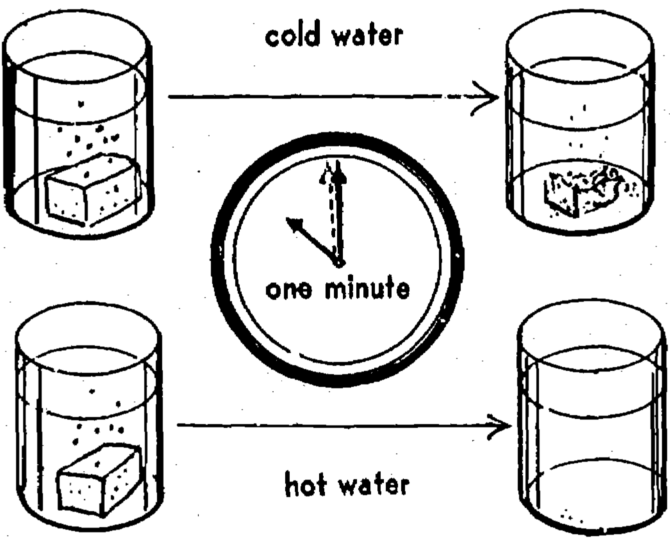
One way is to place an ink-filled dropper near the bottom of the glass and leave it there without squeezing. Observe the contents of the glass the next day.

- *Although we cannot see individual molecules move, we can see evidence of their motion.*
- *A drop of ink spreads in water because the ink molecules move and scatter.*

10. Can we make molecules move faster?

Children may be able to cope with this problem more easily if they first consider this question: In making iced tea, why do we first dissolve the sugar in *hot* tea? Children will recall that sugar dissolves more readily in hot than in cold liquids. They may be led to infer that when something is heated, its molecules move more rapidly.

When water is heated, its molecules bounce around more rapidly. Sugar molecules entering the water are struck by the active water molecules and are scattered more rapidly.



A demonstration which illustrates this principle consists of placing a lump of sugar in a glass of hot water and another in a glass of cold water. Which dissolves more rapidly?

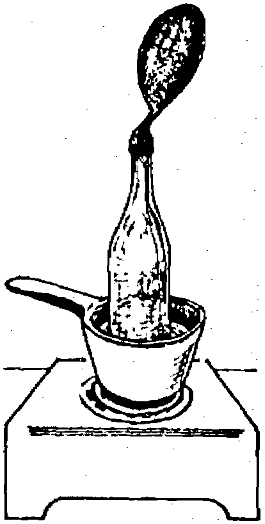
The molecules of all substances, solids, liquids and gases, are in constant motion. The higher the temperature, the more rapid the motion.

- *Raising the temperature of a substance makes its molecules move more rapidly.*
- *Lowering the temperature of a substance makes its molecules move more slowly.*

11. What happens to the size of substances when they are heated?

In Problem 5, the distinction between gases, liquids, and solids was informally introduced. Children noted that in general molecules are far apart in gases, closer together in liquids, and still closer in solids. Review this distinction and then proceed to discuss what happens to the size of each state of matter when it is heated.

a. *Gases.* Snap a balloon over the neck of an "empty" bottle. The bottle is not really empty; it is full of a gas called air. Place the bottle in a basin of warm water to warm the air in it. Children observe that the balloon begins to fill. Why? (As the air in the bottle is heated, its molecules bounce more vigorously and take up more space.) The gas *expands.*



Cool the bottle in a basin of ice water. What happens? Why? In this case the gas *contracts.*

b. *Liquids.* Place a thermometer in cold and then in warm water. Children observe that the liquid in the thermometer rises when it is placed in a warm place. Why?

As the liquid in the thermometer is heated, its molecules move more rapidly. As a consequence they move farther apart. The liquid "grows" or expands. When the thermometer liquid is cooled, the opposite happens. As the molecules slow down they come closer together and take up less space. The liquid "shrinks" or contracts.

c. *Solids.* The solid in this case will be a thin strand of copper wire. Experiment by heating the wire, following the instruction given with the illustration. Hold a lighted match under the wire. Children note that the straw moves as the wire is heated, thus indicating that the wire is lengthening. When the wire cools, it shortens and pulls the straw in the opposite direction.

Ask children why railroad tracks are laid with a small space between the end of one rail and the beginning of the next.

- *Most gases, liquids, and solids expand when they are heated and contract when they are cooled.*
- *Expansion is caused by the moving apart of molecules.*
- *Contraction is caused by the coming together of molecules.*

Evaluative Activities

Select the word, words, or sentences that best complete each of these statements.

1. The smallest particle of common salt is

   a. a tiny speck. c. a pinch.

   b. a molecule. d. a crystal.

   (Answer: b.)

2. When a teaspoon of sugar dissolves in a glass of water it breaks up into

   a. oxygen. c. crystals.

   b. molecules. d. carbon.

   (Answer: b.)

3. When a pan of water dries up, water molecules

   a. scatter into the air. c. are dried.

   b. are destroyed. d. sink into the metal of the pan.

   (Answer: a.)

4. When a cup of alcohol is mixed with a cup of water, the mixture takes up a little less room than 2 cups because

   a. each water molecule becomes smaller.

   b. each alcohol molecule becomes smaller.

   c. the alcohol and water molecules fit more closely into the empty space.

   d. some of the molecules are smashed.

(Answer: c.)

5. In a room with no moving air, we can still smell perfume which escapes from an open bottle because

   a. molecules are always moving.

   b. the perfume bottle is pressurized, so the perfume is shot out.

   c. our organs of smell are attracted to the perfume bottle.

   d. perfume has a strong smell.

(Answer: a.)

6. Although a copper wire is made of separate molecules, it does not fly apart because

   a. the copper molecules have glue between them.

   b. copper molecules are very sticky.

   c. the copper molecules are really attached to each other.

   d. the copper molecules attract each other.

(Answer: d.)

7. An empty balloon is snapped over a bottle which is placed in a basin of warm water. The balloon begins to fill up because

   a. the heat makes the rubber stretch.

   b. when air is warmed, the molecules in it get bigger.

   c. when air is warmed, the molecules move faster and take up more space.

   d. steam from the warm water gets into the balloon.

(Answer: c.)

B. MOLECULES ARE MADE OF ATOMS

BACKGROUND FOR THE TEACHER

In a common experiment performed in junior high school classes, an electric current is passed through some water. As a result two gases are produced which, on testing, prove to be hydrogen and oxygen. If this experiment is continued to its very end, all the water will disappear and in its place there will be hydrogen and oxygen. Careful measurement would show that the weight of the water that disappears is exactly equal to the combined weight of the new gases which have been evolved.

Evidently, water can be "taken apart" to form two new substances. This is possible because each molecule of water is made of two kinds of smaller particles—atoms. Specifically, each molecule of water is made of two atoms of hydrogen and one atom of oxygen. A water molecule, then, is nothing more than a close partnership of two hydrogen atoms and one oxygen atom.

We note that the new substances produced have properties which are distinctly different from the original substance of which they were a part. Hydrogen is a highly flammable gas; oxygen is a gas that supports burning. Water, on the other hand, is a liquid (at room temperature) that does not burn.

When hydrogen and oxygen atoms are linked in a molecule, such as water, the properties they display as unattached atoms are not in evidence. Similarly, when sodium, a white, waxy, poisonous metal is combined with chlorine, a green, poisonous gas, the result is ordinary, edible table salt. The chemist would say that an atom of sodium (Na) plus an atom of chlorine (Cl) forms a molecule of sodium chloride (NaCl).

Approximately 100 kinds of atoms have been identified by scientists. These basic particles form substances known as *elements*. These elementary substances, such as oxygen, hydrogen, carbon, gold, sodium, chlorine, cannot be broken down by ordinary chemical means into any simpler substances. Gold is made only of gold atoms, oxygen of oxygen atoms. Water, sugar and salt, on the other hand, are made of molecules having more than one kind of atom. They are examples of *compounds*. The known compounds identified thus far number approximately one million, but all of these are combinations of the known atoms.

New combinations of atoms are involved in chemical changes such as rusting, tarnishing, burning, sugar-making in plants, digestion of foods and thousands of other everyday phenomena. In all of these, new kinds of molecules are produced by the union or separation of atoms. When iron rusts, for example, iron atoms combine with oxygen atoms to form iron oxide, or rust. If a silver spoon is used for eating an egg, a black layer of tarnish forms on the spoon. The silver combines with sulfur to make the black material silver sulfide. The chemist describes this change in the following equation: $2\ Ag + S = Ag_2\ S$. In other words, he says: two atoms of silver (Ag) combine with one atom of sulfur (S) to form one molecule of silver sulfide (Ag_2S).

APPROACHES AND LEARNINGS FOR THE CHILD

Children investigate some common substances such as water, sugar, and salt and learn that they are made of simpler particles, atoms. They investigate the tarnishing of silver and the rusting of iron and learn how atoms may combine to form new substances. They study charts of the atoms prepared by scientists, and look for examples of atoms in the common things around them.

From the activities suggested, children learn the following:

Molecules are made of atoms.

There are thousands of kinds of substances but only about 100 kinds of atoms.

Molecules are entirely different from the atoms of which they are made.

Changes in the ways atoms are combined are called chemical changes.

1. Why does the scientist call water H two O (H_2O)?

Review previous work on molecules. Children will recall that the smallest amount of water that is water is a molecule of water. Can a water molecule be split into smaller pieces?

Scientists found the answer by running an electric current through the water. When this is done, in a laboratory experiment, hydrogen gas and oxygen gas are released, in the proportion of twice as much hydrogen as oxygen. If this experiment is continued, all the water will eventually disappear, and now in its place we will have large volumes of hydrogen and oxygen. How is it possible for water to be changed into something else?

Water molecules are made of smaller parts. These parts are *atoms*. *Each water molecule is made of two hydrogen atoms and one oxygen atom.* And what is equally important, *every* water molecule has this specific combination of atoms.

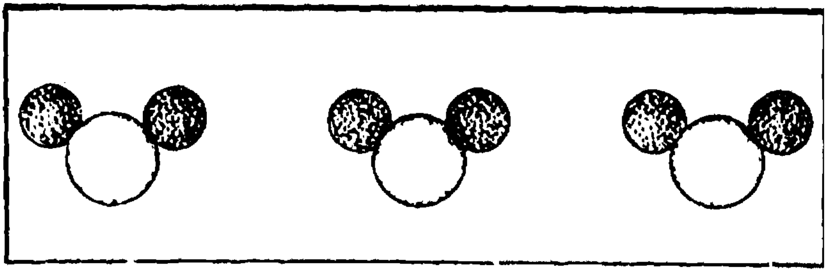
> Pure hydrogen is a combustible gas, lighter than air. It was formerly used in balloons.
>
> Oxygen is a gas which forms about 21% of the air. It supports burning and is essential for all living things.
>
> Yet when hydrogen and oxygen atoms are combined, they form water, a noncombustible liquid.

The letter H is used as a shorthand symbol for hydrogen and O for oxygen. H_2O, the formula for water, means that each water molecule has 2 hydrogen atoms and one oxygen atom.

- *Molecules are made of atoms.*
- *Each water molecule has two hydrogen atoms and one oxygen atom.*

2. What are sugar and salt made of?

a. *Salt.* Observe some salt crystals with a magnifying glass. Note the tiny cubes. Are the molecules of salt in these crystals made of smaller particles? Scientists have found that salt molecules are made of two kinds of atoms: sodium and chlorine. Each salt molecule has one atom of sodium and one atom of chlorine in it. The symbol for sodium is Na. The symbol for chlorine is Cl. The formula for salt is NaCl; the chemical name for salt is sodium chloride.



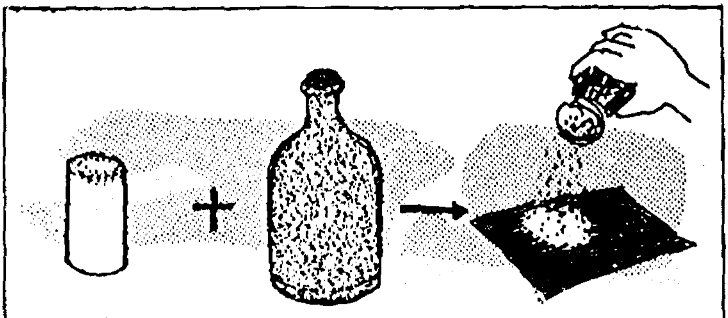
What is salt made of?

Consider the nature of these atoms.

Pure sodium is a white, waxy, poisonous solid.

Pure chlorine is a green, poisonous gas.

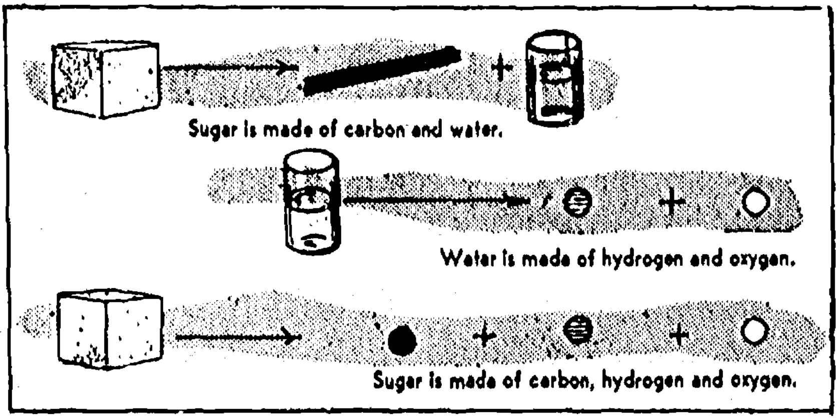
Yet when sodium and chlorine atoms are combined, they form salt, a nonpoisonous white solid which is essential for life.



b. *Sugar.* Children may recall sugar being charred in the process of baking or cooking. (The charring of sugar may be shown in the classroom by heating a lump of sugar in a spoon over a flame.) The black substance that remains on the pan or oven is carbon, similar to the carbon of coal, or charcoal. What is unnoticed in the charring is that water leaves the heated sugar.

When sugar is heated, it breaks down into water and carbon. What does this reveal about the makeup of sugar? It does suggest that sugar is made of carbon and water. What is water made of? Hydrogen and oxygen atoms. Can carbon be split into simpler substances? No, carbon is one kind of atom.

Consequently, sugar is made of three kinds of atoms: carbon, hydrogen, and oxygen.



Consider the qualities of each of these kinds of atoms.

Carbon is a black, tasteless solid.

Hydrogen is a colorless, odorless gas.

Oxygen is a colorless, odorless gas.

Yet all three kinds of atoms combined make sugar, a white, sweet-tasting solid.

- *Sugar molecules are combinations of carbon, hydrogen, and oxygen atoms.*
- *Salt molecules are combinations of sodium and chlorine atoms.*
- *Molecules are not like the atoms of which they are made.*

3. How many kinds of atoms are there?

Review and list on the blackboard the names and symbols of the atoms which have been considered thus far: carbon, hydrogen, oxygen, sodium, and chlorine.

What other atoms are there in our classroom? Children will not necessarily know whether the things they mention are the names of atoms or of combinations of atoms (such as water). They may be guided by the complete list on page 146.

Some of the atoms which children may find in the materials in classrooms are given in the following chart.

ATOM	SYMBOL	WHERE FOUND
Aluminum	Al	pans
Carbon	C	wood, paper, sugar
Chlorine	Cl	salt
Chromium	Cr	faucets, fixtures
Copper	Cu	pennies; electric wiring
Gold	Au	jewelry
Hydrogen	H	water, sugar
Iodine	I	tincture of iodine
Iron	Fe	pipes; radiators
Mercury	Hg	thermometers
Nickel	Ni	coins
Nitrogen	N	air; some foods
Oxygen	O	air, sugar
Silver	Ag	dimes, quarters, half-dollars
Sodium	Na	common salt
Tin	Sn	covering of cans
Zinc	Zn	galvanized iron refuse cans

Look at the list of atoms on page 144. At present scientists have discovered over 100 different kinds. Emphasize the following:

a. Although there are thousands of different kinds of substances, there are only about 100 kinds of atoms.

b. Every substance is made of one or more kinds of atoms.

Each kind of atom is called an *element*. Thus, we may say that there are about 100 elements.

Children may prepare an exhibit of substances, each made principally of one element.

NOTE: The list of elements on page 146 is for teacher reference. Children should not be expected to memorize it.

- *There are about 100 different kinds of atoms, called elements.*

- *All of the substances on earth are made of one or more of these kinds of* atoms.

4. What happens when different atoms join?

Many everyday occurrences involve the joining of atoms. Consider, for example, the tarnishing of silver in which two kinds of atoms, silver and sulfur, join.

To demonstrate this action, place a bit of cooked egg yolk (which contains sulfur) in a small dish. Place the tip of a shiny silver spoon in the egg yolk. After an hour examine the silver spoon.

A thin layer of black material forms. This black material is a combination of silver and sulfur atoms. Chemists call it silver sulfide. Combinations of different atoms such as those in silver sulfide molecules are called *compounds*.

Other examples of compounds are salt, sugar, and water.

Compare the silver sulfide, a compound, with silver and with sulfur, the elements of which it is composed.

Silver is a shiny metal.

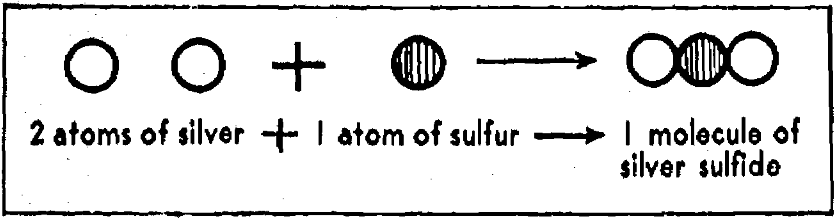
Sulfur is a yellow solid.

Silver sulfide is a dull, black substance.

LIST OF ELEMENTS

Name of Element	Symbol
Actinium	Ac
Aluminum	Al
Americium	Am
Antimony	Sb
Argon	Ar
Arsenic	As
Astatine	At
Barium	Ba
Berkelium	Bk
Beryllium	Be
Bismuth	Bi
Boron	B
Bromine	Br
Cadmium	Cd
Calcium	Ca
Californium	Cf
Carbon	C
Cerium	Ce
Cesium	Cs
Chlorine	Cl
Chromium	Cr
Cobalt	Co
Copper	Cu
Curium	Cm
Dysprosium	Dy
Einsteinium	Es
Erbium	Er
Europium	Eu
Fermium	Fm
Fluorine	F
Francium	Fr
Gadolinium	Gd
Gallium	Ga
Germanium	Ge
Gold	Au
Hafnium	Hf
Hahnium	Ha
Helium	He
Holmium	Ho
Hydrogen	H
Indium	In
Iodine	I
Iridium	Ir
Iron	Fe
Krypton	Kr
Lanthanum	La
Lawrencium	Lw
Lead	Pb
Lithium	Li
Lutetium	Lu
Magnesium	Mg
Manganese	Mn
Mendelevium	Md
Mercury	Hg
Molybdenum	Mo
Neodymium	Nd
Neon	Ne
Neptunium	Np
Nickel	Ni
Nitrogen	N
Niobium	Nb
Nobelium	No
Osmium	Os
Oxygen	O
Palladium	Pd
Phosphorus	P
Platinum	Pt
Plutonium	Pu
Polonium	Po
Potassium	K
Praseodymium	Pr
Promethium	Pm
Protactinium	Pa
Radium	Ra
Radon	Rn
Rhenium	Re
Rhodium	Rh
Rubidium	Rb
Ruthenium	Ru
Samarium	Sm
Scandium	Sc
Selenium	Se
Silicon	Si
Silver	Ag
Sodium	Na
Strontium	Sr
Sulfur	S
Tantalum	Ta
Technetium	Tc
Tellurium	Te
Terbium	Tb
Thallium	Tl
Thorium	Th
Thulium	Tm
Tin	Sn
Titanium	Ti
Tungsten	W
Uranium	U
Vanadium	V
Xenon	Xe
Ytterbium	Yb
Yttrium	Y
Zinc	Zn
Zirconium	Zr

Silver sulfide is not just a mixture of silver and sulfur. You cannot find pieces of shiny silver or yellow sulfur in it. Silver sulfide, the compound, is completely different from its elements. This is true of all chemical compounds.



In the tarnishing of silver, two atoms of silver combine with an atom of sulfur to form one molecule of silver sulfide. Every silver sulfide molecule is made of two silver atoms and one sulfur atom.

- *Elements join together to form compounds.*

- *Compounds are completely different from the elements in them.*

5. What happens when iron rusts?

Place some moistened steel wool in a dish for several hours. The steel wool turns reddish brown. What change has taken place?

Steel is mostly iron. Iron combines with the oxygen in the air to form iron oxide, commonly known as rust. Iron oxide is different from the elements iron and oxygen.

Iron is dull, gray solid.

Oxygen is a colorless gas.

Iron oxide is a red, crumbly solid.

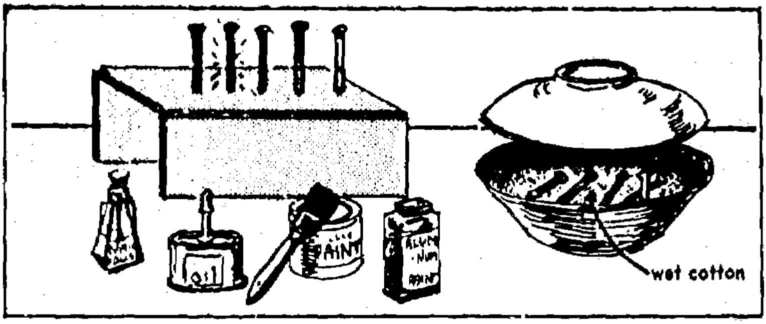
Changes in atom combinations, such as in rusting or tarnishing, are called chemical changes. (Water helps rusting because it speeds up the chemical union of iron and oxygen.)

- *The rusting of iron results from the combining of iron atoms with oxygen atoms.*

- *Changes in the ways atoms are combined are called chemical changes.*

6. How can we prevent iron from rusting?

List some of the children's ideas for preventing the rusting of iron. Test proposals on a number of iron nails. Stand the nails upright in a piece of cardboard, as shown in the illustration. Treat the nails with such substances as oil paint, aluminum paint, machine oil, fingernail polish, fat. Leave one or two nails untreated. Place all the nails in a bed of soaking wet cotton and then cover them. After several days examine, and discuss results.



Covering the nails prevents rusting because it keeps water and oxygen away from the iron. It prevents oxygen atoms from combining with iron atoms. Consequently no rust (iron oxide) forms.

Discuss ways in which rusting is prevented in the home.

Oil is smeared on tools after use.

Radiators and pipes are painted.

Garbage cans are made of iron coated with zinc (galvanized iron).

Iron bathtubs and sinks are covered with porcelain.

Food cans are made of steel (mostly iron) coated with a thin covering of tin.

Stainless steel kitchen knives are made of steel and chromium.

- *We can prevent rusting by covering iron objects with other metals, oil, paint, and porcelain.*

- *Covering the surface of an iron object prevents rusting because it keeps water and oxygen away from the iron.*

Evaluative Activities

Select the correct word, words, or sentences to complete each of these statements.

1. Scientists call water H_2O because each water molecule is made of

   a. 1 hydrogen atom and 1 oxygen atom.

   b. 2 hydrogen atoms and 1 oxygen atom.

   c. 1 hydrogen atom and 2 oxygen atoms.

   d. 2 hydrogen atoms and 2 oxygen atoms.

   (Answer: b.)

2. When iron rusts,

   a. oxygen and iron atoms join.

   b. oxygen and iron atoms separate.

   c. iron atoms turn a brown color.

   d. iron atoms fall apart.

   (Answer: a.)

3. Combinations of different atoms in molecules are called compounds. Which of the following are compounds?

a. silver	c. water	e. salt	g. sugar
b. sulfur	d. oxygen	f. carbon	h. hydrogen

   (Answer: c., e., g.)

4. Which of the following statements is true?

   a. There are thousands of kinds of atoms but only hundreds of kinds of substances.

   b. There are thousands of kinds of atoms and thousands of kinds of substances.

   c. There are about a hundred kinds of atoms and a hundred kinds of substances.

   d. There are about a hundred kinds of atoms but thousands of kinds of substances.

   (Answer: d.)

C. ATOMS ARE MADE OF SMALL PARTICLES

BACKGROUND FOR THE TEACHER

Atoms are made of small particles. Although several dozen of these particles have been identified by scientists, we will consider only three: *electrons, protons,* and *neutrons.*

Protons and neutrons form the center or nucleus of each atom; electrons whirl around outside the nucleus.

Electrons are extremely light atomic particles possessing a type of electricity which has been designated as a *negative charge*. Protons are about 2000 times as heavy as electrons; they possess a *positive charge* of electricity. Neutrons weigh about the same as protons, but, as their name implies, are electrically neutral; that is, they have no electrical charge.

Static electricity is studied here in relation to atomic structure for two reasons:

1. Static electricity *reveals* the electrical makeup of matter; it suggests the possibility of the existence of negatively and positively charged particles within the atoms of matter.
2. Static electricity *is explained* best by reference to the theory of atomic structure.

Further background material on static electricity is incorporated in the development of the problems.

APPROACHES AND LEARNINGS FOR THE CHILD

The word atom, first used by the Greeks, means indivisible. Until the turn of this century atoms were thought of as hard, unbreakable particles. The work of many scientists revealed that atoms were made of smaller particles and that atoms could split.

Obviously young children cannot conduct many experiments on or make many direct observations of atomic particles. In studying static electricity, however, children do find evidence of the existence of electrical particles in atoms. In studying models and charts of atomic structure, children draw conclusions from data which has been produced by the work of scientists. From the activities suggested, children learn these facts:

Atoms are made of electrons whirling around a central nucleus.

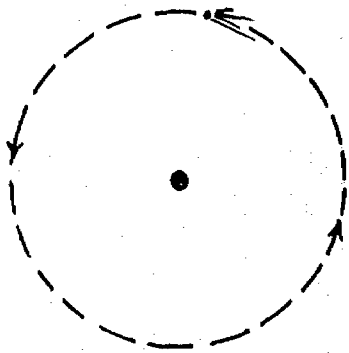
Atoms are made of electrons, protons, and neutrons.

Atoms of different elements differ in the number of particles of which they are made.

1. Why does a comb crackle sometimes when it is drawn through the hair?

Encourage children to tell of experiences in which they heard, saw, or felt electric sparks, such as in combing hair, taking off a nylon or orlon sweater, walking across a rug and touching a metal object. Where does the electricity come from?

Recall that all substances are made of molecules, and that all molecules are made of atoms. When a comb is drawn through the hair, atoms in the comb are rubbing against atoms in the hair. What does all this have to do with electricity?

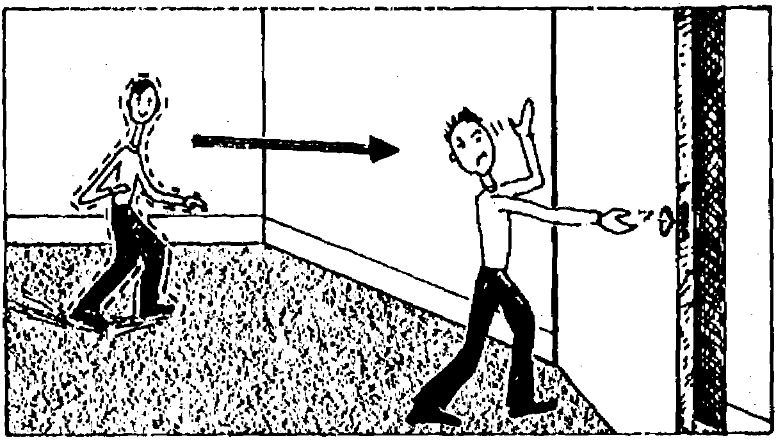


Late in the nineteenth century, it was discovered that atoms are made of smaller particles. Each atom has one or more particles called *electrons* whirling around a central part called a *nucleus*.

When a rubber comb is rubbed on hair, some of the electrons from the atoms of the hair are torn away from it and deposited on the comb. The comb, therefore, has a "surplus" of electrons while the hair has a "deficit". Both the comb and the hair are said to have acquired an electric charge.

Rubbing has produced a charge in both the comb and the hair by causing a transfer of electrons. Note, however, that the electric charge is possible because of the fact that *atoms are electrical in their makeup*.

Scuffing one's shoes on a rug also builds up a charge because electrons are torn away from the rug and deposited on the shoes. The electrons do not stay on the shoes but flow all over the surface of the body, which is now "charged". When the charged person touches a metal doorknob, billions of electrons jump at once from the skin to the knob, giving the person a tiny shock.



Gaining and losing electrons.

The electricity produced by building up an electrical charge on a surface is known as *static electricity.*

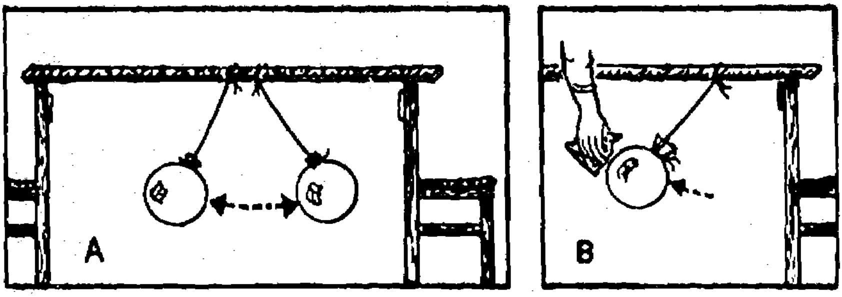
- *In atoms, electrons whirl around a central nucleus.*
- *Rubbing produces electric charges because electrons are torn off the atoms of one surface and deposited on another.*
- *Such charges are known as static electricity.*

2. Why do two balloons move away from each other after being rubbed?

a. Rub two blown-up balloons with a piece of wool. Suspend each by a string about two feet long. Note that the two balloons move away from each other? Why?

Both balloons have picked up billions of electrons from the wool. Both have acquired an electric charge. Both charges are similar. But the balloons appear to repel each other. We can conclude that similar charges of electricity repel each other.

b. Now move the piece of wool near one of the suspended balloons. Note how the balloon is attracted to the wool. Why does this happen?



Again we go to the atom for an answer, this time to its center, the nucleus. The nucleus of an atom contains a number of different kinds of particles. One of these is the proton. When we rub wool against the balloon, we are stripping away some of the electrons from the wool's atoms. We do not, however, remove the protons. The attraction of balloon to wool is the *attraction of electrons to protons.*

Scientists have arbitrarily designated the charge on electrons as *negative* and the charge on the protons as *positive.* The attraction of balloon to wool is the result of the attraction of the balloon's electrons to the wool's protons.

The repulsion between the two charged balloons is due to the repulsion between the electrons on each.

- *Objects with similar electrical charges repel each other.*
- *Objects with opposite electrical charges attract each other.*
- *Atoms contain electrons (particles with a negative charge of electricity) and protons (particles with a positive charge of electricity).*

3. Why does your hair stand on end?

Comb or brush your hair vigorously. On a dry day, particularly when your hair is free from natural oils or hair preparations, your hair may stand on end. Why? Rubbing, as we saw previously, removes electrons from the hair. Each strand of hair thus gets a positive charge. Being similarly charged, each strand of hair repels its neighbor, and so the hair tends to stand on end.

- *Rubbing your hair may remove electrons from it, leaving the hair with a positive charge.*

- *Objects with similar electrical charges repel each other.*
- *Similarly charged strands of hair repel each other.*

4. What is lightning?

Ask children to recall their experiences during a lightning storm. Compare the lightning flash with the small spark they notice when they shuffle on a rug and touch a metal object. This spark is similar to lightning; both result from the sudden flow of electrons.

The production of high electric charges in thunderstorms is a complex process, not fully understood. It is thought that the water droplets in a cumulus cloud are continuously torn apart by swirling air currents. As a result the droplets become electrically charged. Eventually the thundercloud builds up enough electricity to cause a discharge. We see this as a flash of lightning. The discharge may take place within the cloud, between one cloud and another, or between the cloud and the earth.

- *Lightning is a gigantic electric spark.*
- *In some way, perhaps by the friction of water droplets with the air, static electricity builds up in a cloud.*

5. What is current electricity?

Ask students to recall their work in Grade 5 on "Batteries and Bulbs."

The following summary of Background for the Teacher for this topic is useful in discussing the nature of current electricity.

> Electricity must have a complete circuit in order to flow. The circuit is the path that the electrons follow from a source of energy (a flashlight battery), through the device to be operated, and then back again to the source of energy.
>
> To understand electricity, it is essential to know something about electrons. Electrons are particles found in the atoms of all substances. In a basic sense, therefore, all substances are electrical in nature. Thus, it is not possible to "make" electricity; all that is

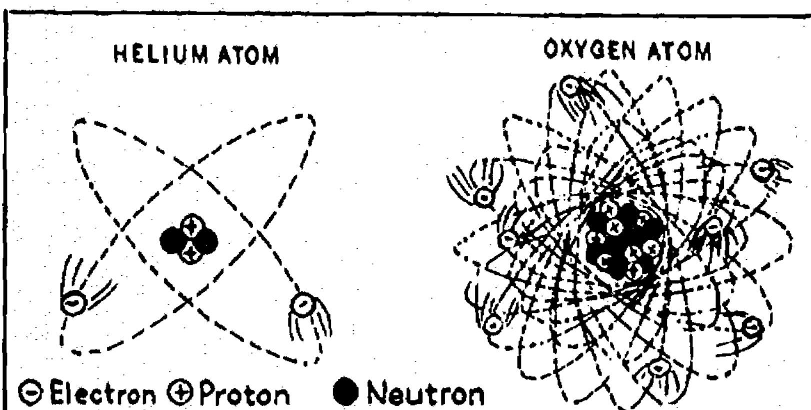
needed is a "push" to start a flow of electrons in one direction. Current electricity, then, is a stream or a *flow of electrons.* This stream or current flows in a continuous path from a source of energy, through the device to be operated, back again to the source of energy, and so on. This complete path is called a circuit. The current will not flow unless the circuit is unbroken (complete).

When we say that electricity flows through a copper wire in a circuit, what really happens is that each atom of copper in that wire is passing some of *its* electrons on to neighboring atoms. The neighboring atoms do the same, and so on along the wire.

- *Current electricity is a flow of electrons.*
- *Electrons are part of the atoms of all matter.*

6. What is inside an atom?

The previous activities have indicated that atoms have electrons whirling around a central nucleus, that inside the nucleus are protons, that electrons and protons have opposite electrical charges.



A third particle, found inside the nucleus of the atom, is the neutron. As its name implies, it is electrically neutral, having neither a positive nor a negative charge.

- *Atoms are made of electrons, protons, and neutrons.*

Evaluative Activities

Select the word, words, or sentences that best complete each of the following statements.

1. Two blown-up balloons that are rubbed with a piece of wool move apart because

   a. rubbing irritates the rubber.

   b. they have different electrical charges.

   c. they have the same electrical charge.

   d. they are not charged at all.

   (Answer: c.)

2. If you comb your hair vigorously on a dry day, it stands on end because the hairs have acquired a positive charge since they have lost

   a. protons. b. atoms. c. electrons. d. neutrons.

   (Answer: c.)

3. The body of an automobile sometimes builds up a large electrical charge because

   a. it has an electrical battery inside.

   b. its motor produces electricity.

   c. it has a body which is largely metal.

   d. its tires rub against the road.

   (Answer: d.)

D. FINDING OUT MORE ABOUT MOLECULES AND ATOMS

(Enrichment Activities)

This section lists special projects for interested pupils who should be encouraged to present their findings and demonstrations to the class.

The books listed in the Bibliography have many more suggestions for demonstrations and experiments.

1. Crystals of various substances can be grown by suspending a string in a solution of the substance. As atoms or molecules are deposited, crystals are formed.

2. Make 3-D models of molecules. For atoms use disks, plastic clay, sponge rubber balls, or styrofoam balls. For links between atoms use sticks, wire, pipe cleaners, or toothpicks.

3. Make models of atoms from materials similar to those in Problem 2. Show electrons, protons, and neutrons of various atoms. Have children compare their models with accurate descriptions of the structure of atoms, in order to make clear the limitations of the models.

4. Observe flashes from self-splitting atoms. At home at night observe a watch or clock with a luminous dial. Turn out the lights; wait 10 minutes for the eyes to become adjusted to the darkness. Note the soft glow from the dial. Hold a strong magnifying glass near the eye and move the watch or clock until it is in sharp focus. Instead of a soft glow, a shimmering, sparkling light will be observed. The sparkling flashes are caused by particles from the splitting atoms striking a chemical (zinc sulfide) on the hands and numbers.

5. Have a committee of students find out where current exhibits concerning the study of atoms and molecules are being held and make arrangements, under the teacher's guidance, for a class visit.

BASIC SUPPLY LIST

For Molecules and Atoms

*Indicates quantity for entire class; other quantities specified are for each group of 2 or 4 children.

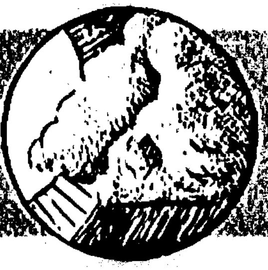
STOCKED SUPPLY LIST

Magnifying glass
2 Measuring cups
Thermometer
Few strands of copper wire
2 Balloons
*1 Bottle of alcohol
*1 Hotplate
*Package of dark paper

Hammer
Medicine dropper
Glass dish
Stainless steel spoon
2 Glass tumblers
Ruler
6 Nails
*Roll of waxed paper
*Small bottle of oil
*Bottle of ink
*Roll of steel wool
*Small can of oil paint
*Pan

MISCELLANEOUS

Stones
Jar
2 or 4 Rubber combs
Piece of wool cloth
*Vial of inexpensive perfume
*Box of matches
*Box of table salt
*Silver spoon
*Cooked egg yolk
*Small can of aluminum paint
*Bottle of fingernail polish
*Some grease or fat
*Ball of string
*Box of lump sugar
*Box of granulated sugar
*Box of toothpicks
*Roll of plastic wrap
*Bag of walnuts
*Box of dried peas



The Ocean of Air

A. THE AIR AROUND US

BACKGROUND FOR THE TEACHER

Man lives at the bottom of an ocean of air which extends upward for several hundred miles. We have become more aware of this enveloping air ocean as a result of the journeys of astronauts in airless space. To survive in space, astronauts have had to carry part of the earth environment with them: air to breathe; enough air pressure to prevent their bodies from exploding in the vacuum of space; heating devices to protect them against the extreme cold of space; shields against harmful radiation.

Air is a real substance: it is made of molecules; it has weight; it takes up space; it resists the motion of objects through it. The two most abundant parts of the atmosphere are nitrogen, which accounts for nearly four-fifths of the air, and oxygen which makes up about one-fifth. Oxygen is essential to the respiration of plants and animals, and for the burning of fuels. Carbon dioxide, constituting only $\frac{3}{100}$ of 1% of the air, and water vapor, found in amounts varying from zero to 3 or 4% are also important for life.

Air at rest exerts pressure because of its weight. However, we usually are not aware of this pressure because it pushes on us equally in all directions, and because the air in our body cavities and the blood in our arteries and veins push our body structures outward with equal pressure.

At sea level, the pressure the air exerts is about 15 pounds on every square inch of surface. Since air is an elastic substance its pressure is exerted equally in all directions. As one might expect air pressure decreases as we go up since at higher altitudes there is a smaller amount of air above us.

APPROACHES AND LEARNINGS FOR THE CHILD

The study of air is closely related to the study of two other areas considered in the sixth-grade science program. The topic "Molecules and Atoms" (pages 125 to 158) helps children understand the physical makeup of air. The topic "Moving in Air and Space" applies the understanding of the nature of air to the problems of flight.

From the activities suggested, children learn that:

Air is real: it occupies space; it has weight; it presses on objects.

Air gets thinner as we go up in the atmosphere.

Air pressure decreases as we go up in the atmosphere.

Air contains nitrogen, oxygen, carbon dioxide, water vapor, dust.

1. Is air a real substance?

Discuss what *real* means. What makes a book a real thing? (It has weight; I can touch it; it takes up space; it presses on my hand; it makes a sound when I hit it; it can hold something up, for example another book; I can see it; it stops my hand from moving.) Ask how one can prove that air is real. List on the chalkboard suggestions and activities offered.

If air is real, it should	To prove that air is real, we
Have weight.	Weigh it. (Compare the weight of a full balloon and an empty one on a balance.)
Hold something up.	Place a book on a plastic bag or balloon with air in it.
Make a sound when it is hit.	Hit a paper bag full of air with both hands.
Be able to slow down something moving through it.	Drop a sheet of paper.
Be able to push against something.	Fly a kite.

The preceding chart may be helpful in pooling the thinking of the children. *It is offered as a sample only* and suggests some of their responses. The methods of proof proposed may be difficult or impossible to carry out, but the creative thinking that is involved is of value.

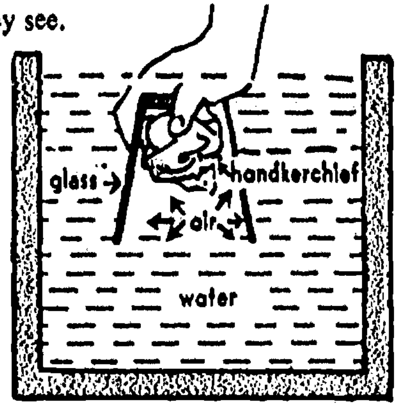
From the discussion, a basis is laid for considering the problems which follow. Proposals which are not covered by these problems should be considered. As far as possible, allow children to try out their ideas.

- *A real thing has weight and takes up space.*
- *If air is real, we should be able to prove it in a number of ways.*

2. Does air take up space?

A classic demonstration follows. Stuff a handkerchief into the bottom of a dry, empty drinking glass. Then invert the glass and carefully lower it straight down into a bowl of water. Do not tip the glass.

Ask the students to describe what they see.



Does water go into the glass? (A small amount goes in.)

How can they be sure? Remove glass by lifting it straight up. Take handkerchief out of glass and allow students to feel it.

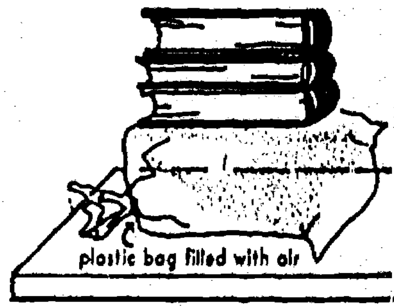
Why is it dry? (No water reached the handkerchief.)
Why didn't water fill the glass? (Air was in the space in the glass and prevented the water from going in.)

- *Air occupies space.*
- *Air is a real substance.*

3. Can air hold something up?

Wave a plastic or paper bag through the air. When the bag fills up, twist and close the opening. Tie it tightly with a string.

Ask the children what is in the bag. (Air.) How can we show that the bag can hold something up? Place several books on top of the bag. What happens? Why doesn't the bag flatten out? What is actually holding the books up? (Air.) How can you prove it? (Release the string. As the air escapes, the bag is flattened and the books come down.)



Does air hold up an automobile? (Yes. The air in the tires holds it up.)

- *Air can hold up objects.*

- *Air is a real substance.*

4. What does air do to falling objects?

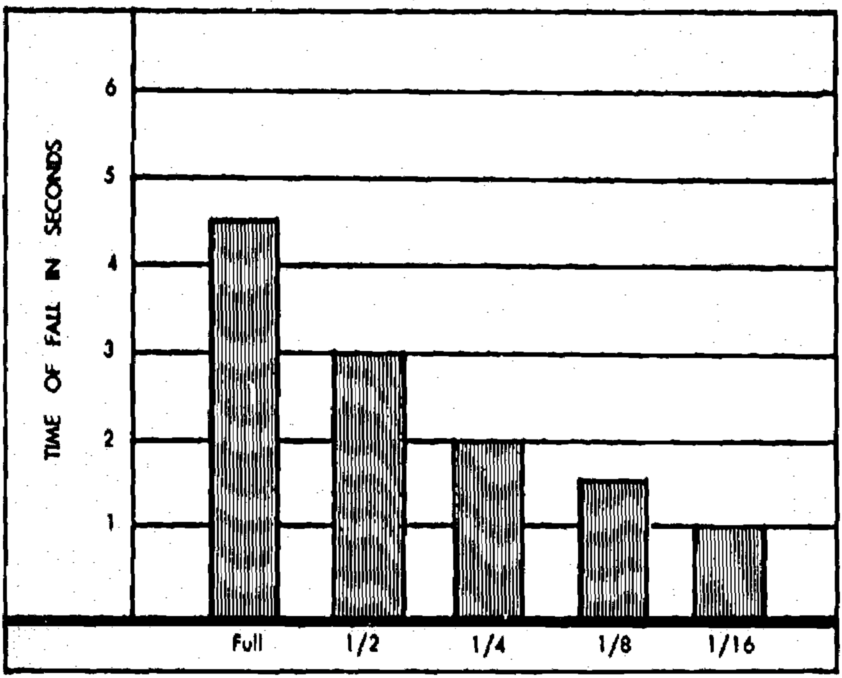
Hold a sheet of paper horizontally and allow it to drop. (Stand on a chair and hold paper as high as possible.) Ask children to describe the path of movement of the paper and the time taken for the descent. Ask children to predict what would happen if the paper were crushed into a small ball and dropped from the same height.

Try it and have children compare the paths of flight (the crushed paper falls straight down, while the open one glides from side to side) and the time taken for each fall.

If there is some doubt about the time, repeat the demonstration, dropping two sheets of paper, one opened, one crushed, at the same time; or time the fall of each with the second hand of a watch or a stopwatch.

Why is there a difference? (Air slows the falling paper. The open sheet is supported by more air and is slowed more.)

Compare with the second hand of a watch or a stopwatch the time taken for the fall of a sheet of paper, first open, and then successively folded in half, quarters, eighths, and sixteenths of the original size. (To prevent the smaller size from opening up it may be necessary to tear and fold a paper tab across the open side.) In each case the paper should be held horizontally and dropped from the same height (i.e., from as high as possible). Make a table and a graph such as the following to summarize the results. (Results may be different, depending on the size of the original sheet and the distance of fall.)



Ask children to summarize their findings. Is there a relationship between the size of the paper and the time needed for the fall? (Yes.) What is the relationship? (The more the paper is folded, the faster it falls.) Why? (The smaller the sheet, the less air it strikes.)

What would happen if you performed the paper-folding experiment on the moon? (All papers would fall in the same amount of time.) Why? (The moon is airless. There is nothing to slow the falling paper.)

NOTE: All objects fall more slowly than on earth because the moon's gravity is only about 1/6 that of the earth's gravity.

Astronauts returning to earth use parachutes attached to the space capsule. Why? (Parachutes expose more surface to the air and slow the descent.) Do space ships landing on the moon use parachutes? (No.) Why not? (There is no air there to slow down the ship.)

What is there about air that makes it slow falling objects down? (Air is a real substance. It is made of tiny particles which touch objects moving through it.)

What happens to rocks from outer space when they enter the earth's atmosphere? (Traveling at great speed, the rocks are heated by friction as they rub against the molecules in air.) Most of the rocks burn up. We call them shooting stars although they are meteors, not stars.

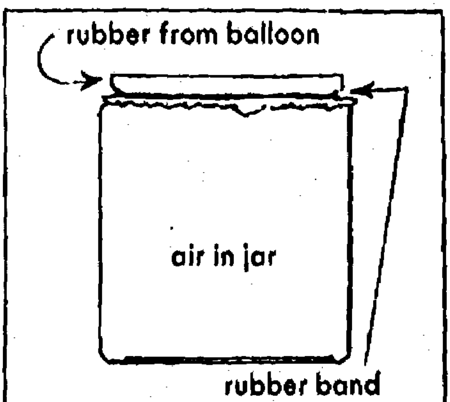
- *Air slows down objects that fall through it.*

- *Air is a real substance.*

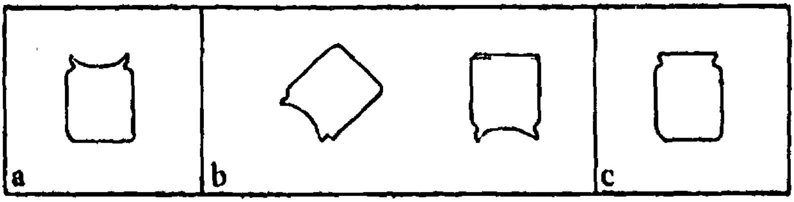
5. Does air press on objects?

In the topic "Molecules and Atoms" (see page 125) the children studied the effect of heat on air. A balloon was snapped over the neck of a bottle. When the bottle was placed in warm water, the balloon filled. When it was placed in cold water, the balloon collapsed. Children concluded that heating made air expand; cooling made it contract. This was related to the concept that air consists of moving molecules. Heating made the molecules move about more vigorously, causing the air to expand and inflate the balloon. Cooling resulted in the reverse action.

The force or "push" of air molecules is the cause of *air pressure*. To emphasize the concept of air pressure, have the children conduct the experiment suggested here.



With a pair of scissors cut a flat sheet of rubber from a large balloon. Place it over the mouth of a small screw top jar; spread it firmly across it, but do not stretch it. Fasten it to the jar with a rubber band. Note the shape of the rubber on the jar. (It is flat.)



a. Ask children, "What happens if the air in the jar is cooled?" Place the jar into a container of cold water. Children note that the sheet of rubber moves down. It is stretched *in*. Why? From previous experiments children recall that when air is cooled, its molecules do not move about vigorously. The air contracts; that is, it takes up less space.

   But why should the sheet of rubber move in? What stretched it *in*? What *pushed* it in? Children may hypothesize that the air *outside* the jar, that is, the air in the room pushed *harder* against the rubber than the air in the jar and forced the rubber in. We call this pushing *air pressure*.

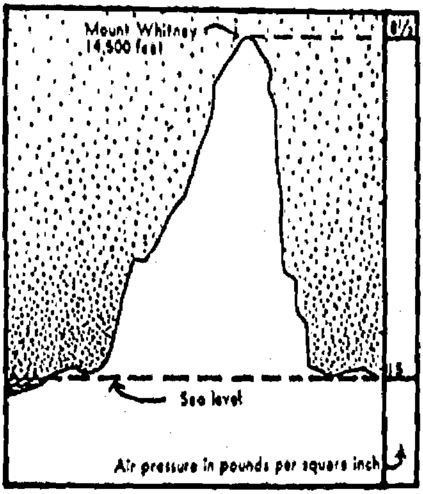
b. Does the outside air push in all directions? Hold the jar (with the cooled air) in a number of positions: sidewise, upside-down, etc. The rubber sheet remains pushed in. The pressure of the air is exerted equally in all directions.

c. Allow the jar to warm up to room temperature. Children note that the sheet of rubber is restored to its original flat shape. Why? The air in the jar warms; its molecules push harder; it expands; it pushes as hard against the rubber as the outside air. The *air pressure* is the same on both sides of the rubber.

- *The air around us presses on objects.*
- *Air pressure is exerted in all directions.*
- *Air is a real substance.*

6. What happens to air pressure as we go up in the atmosphere?

Ask children to discuss the statement: We live at the bottom of an ocean of air. Ask them about experiences they may have had or read about in diving deep under water. They may recall the increased pressure they felt in their eardrums or chests. Water presses because it has weight. The deeper we dive the more water there is above us, hence the pressure of the water increases. Air, like water, has weight. This weight of air presses on all sides of us. As we go higher into the atmosphere, less air is above us and so less air presses on us. The pressure on mountain tops is less than the pressure at sea level.

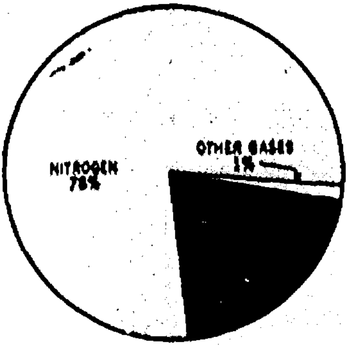


Ask the children if they recall experiencing a feeling of pressure on their eardrums when they have gone up or down rapidly in an elevator, or when a car in which they are traveling goes up or down a long steep incline. When descending, the pressure of the outside air on the eardrums increases. When ascending, the pressure of the outside air on the eardrums decreases; the air on the inside of eardrums presses outward on them.

- *Air presses on us.*
- *The air gets thinner as altitude increases.*
- *Air pressure drops as altitude increases.*

7. What is air made of?

Recall experiments conducted in Grade 5 (see *Science: Grade 5*, pages 43-45) in which a candle burns under an inverted glass. After a short time the candle goes out because one part of the air, oxygen, is used up in the process. Oxygen is needed for the combustion of fuels, and to sustain life in living things.

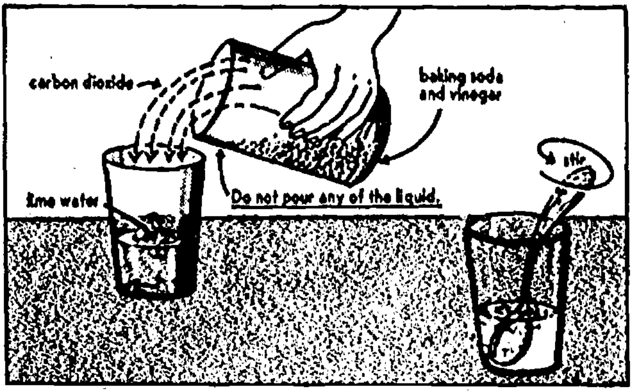


The circle (see illustration) summarizes the composition of air in percentages. In connection with this study, students may read and report on the various components of the air.

- *Air is a mixture of a number of gases.*
- *Most of the air consists of nitrogen and oxygen.*

8. How can we detect carbon dioxide in the air?

a. How to test for carbon dioxide



A well-known chemical for detecting carbon dioxide is clear limewater, available at drugstores. To demonstrate the effect of carbon dioxide on limewater, make carbon dioxide by stirring some baking soda into vinegar. "Pour" the gas produced into a glass containing some limewater, and stir. The limewater turns a milky color.

b. Carbon dioxide in our lungs

A good deal of carbon dioxide is in air breathed out of the lungs.

To show that this is so, have children blow bubbles through the limewater, using a drinking straw or plastic tubing.

The children note that the limewater turns a milky color.

c. Carbon dioxide from a burning candle

Place a lighted match or candle in an upright jar for a little while. Remove the match or candle, keeping the jar upright, and pour some clear limewater into the jar. Swish the limewater around and it should turn milky. Why? (When fuels containing carbon are burned, carbon dioxide is produced.)

d. Carbon dioxide in the air

Fill two small jars with limewater. Cover one with its lid and allow both to stand overnight. The next day the limewater in the open jar should be milky, but the limewater in the closed jar should still be clear. Why is this? (Air contains carbon dioxide.)

- *Air contains carbon dioxide gas.*
- *We breathe out carbon dioxide.*
- *When fuels containing carbon are burned, carbon dioxide is given off.*

9. How can we detect water vapor in the air?

Place ice cubes in a tumbler of water. Stir the ice and water mixture. The children see a film of water form on the outside of the glass. Where does the water film come from? (It comes from the air.) How do you know that it does not come from the water? (Water can't leak through the glass.) How can you *prove* that the water comes from the air? (Chill a dry glass in a refrigerator, or place it out of doors on a cold day. Then expose it to the warm, moist air in the room. A film of water should form on the glass.)

The largest source of water vapor in the air is from the evaporation of water from oceans and other large bodies of water. To show that living things also give off water, breathe on a mirror or cool blackboard. Observe the condensed vapor.

Review the principles of evaporation and condensation developed in Grade 5. (See *Science: Grade 5*, pages 26-30.)

- *When water evaporates, it becomes invisible water vapor.*
- *Water vapor is invisible.*
- *Living things give off water vapor.*
- *When water vapor condenses, it becomes visible water.*

10. How do dust and smoke in the atmosphere affect us?

The air around us contains not only gases but tiny particles of dust. Dust and smoke in the air around us come from many sources: factory smokestacks, volcanoes, pollen from plants, spores from flowerless plants, automobile exhausts.

Dust in the air is important for the condensation of water vapor. Dust particles in the air serve as centers for nuclei on which tiny droplets of water form. If there were no dust particles in the air, clouds could not form and we would have no rain or snow.

Dust in excess is harmful. Smog, a mixture of smoke and fog, occurs when smoke, imprisoned in lower, foggy layers of air, produces a dark, uncomfortable atmosphere. In addition to reducing visibility, smog irritates the eyes, nose, and throat, making breathing difficult and damaging vegetation.

Many cities are taking steps to reduce pollution of the air. Have children report on New York City regulations with respect to the burning of coal, oil, and leaves. Report also on the efforts of Los Angeles to reduce smog by requiring the placing of special mufflers on automobiles, to reduce the contaminating effects of exhaust fumes.

Have the class read about the evils of air pollution. There are many books and pamphlets in public libraries on this timely subject. Discuss the origins of this hazard, its effects on people, plants, weather, buildings, and clothes. Have class give ideas for reducing air pollution.

Collecting Dust to Measure Air Pollution

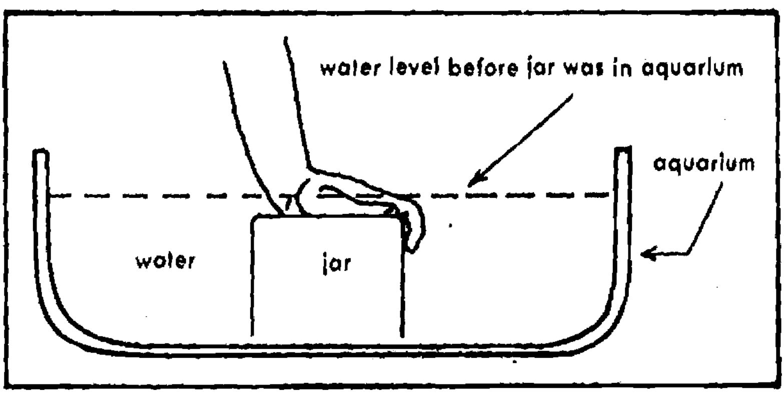
Lay sheets of white paper in different sections of the house; near open windows, under beds, in kitchen. For outdoor collections place white paper on bottom of deep cartons. Leave the open cartons in various locations; near chimneys, factories, residential and industrial locations. Also place in strategic spots, indoors and outdoors, some dust collectors made of scotch tape with the sticky side facing upward. Another kind of sticky dust catcher is a piece of cardboard smeared with vaseline or similar grease. Still another collector is an open large-mouthed jar containing a little water. When the water evaporates you can see the amount of dust collected. Label each dust-catcher and compare the amount from each location. Examine each with a magnifying glass.

- *Smog is a mixture of smoke and fog.*
- *Air pollution is harmful to living and nonliving things.*
- *Air pollution can be reduced through the cooperation of many people.*

Evaluative Activities

Work out the following problems.

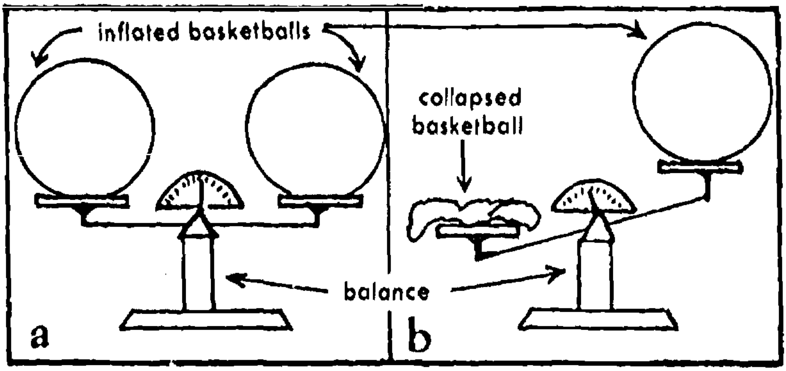
1. An empty jar is turned upside down and pushed into an aquarium filled with water.



a. Draw a line to show the level of the water in the jar. (The level is at or near the open end.)

b. Draw a dotted line to show the new level of the water in the aquarium. (It is higher than the original level.)

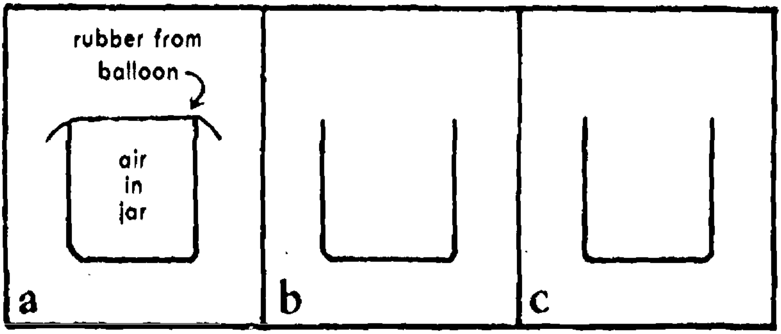
2. Picture (a) shows two basketballs on a scale. In Picture (b) one basketball is deflated. What is wrong with Picture (b)? (Scale should be tipped down on side of inflated basketball.)



3. Why is a parachute useless on the moon? (There is no air to slow its fall.)

4. Using Pictures (a), (b), and (c), work out these problems.

a. Picture (a) shows a jar with air at room temperature. Draw the rubber sheet in Picture (b) as it would look if the jar were placed in hot water. (It bulges up.) Why does it look this way? (The air in the jar is heated by the water. Heated air takes up more space, thus pushing rubber sheet up.)

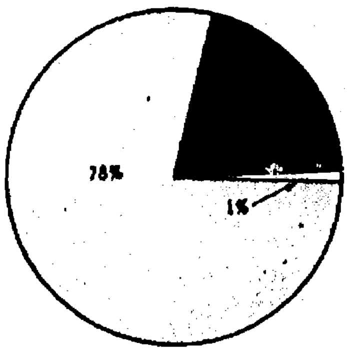


b. In Picture (c) draw the rubber sheet as it would look if the jar were placed in cold water. (It bulges down.) Why does it look like this? (Cooled air takes up less space; outside air pushes the sheet down.)

c. What would happen to the rubber sheet if the jar (c) were turned sidewise? (It remains the same.) Upside down? (It remains the same.) Why? (Air presses equally in all directions.)

5. Pike's Peak in Colorado rises 14,109 feet above sea level. Why do some people develop nosebleeds as they go up this very high mountain? (Air pressure diminishes as we go higher up, but pressure in our bodies remains the same as it was at sea level. The inner pressure is greater than the outside air pressure, and sometimes small blood vessels burst.)

6. This circle represents the percentages of the gases making up the air around us. Use the words *nitrogen*, *oxygen*, and the names of *other gases* to label each part of the circle.

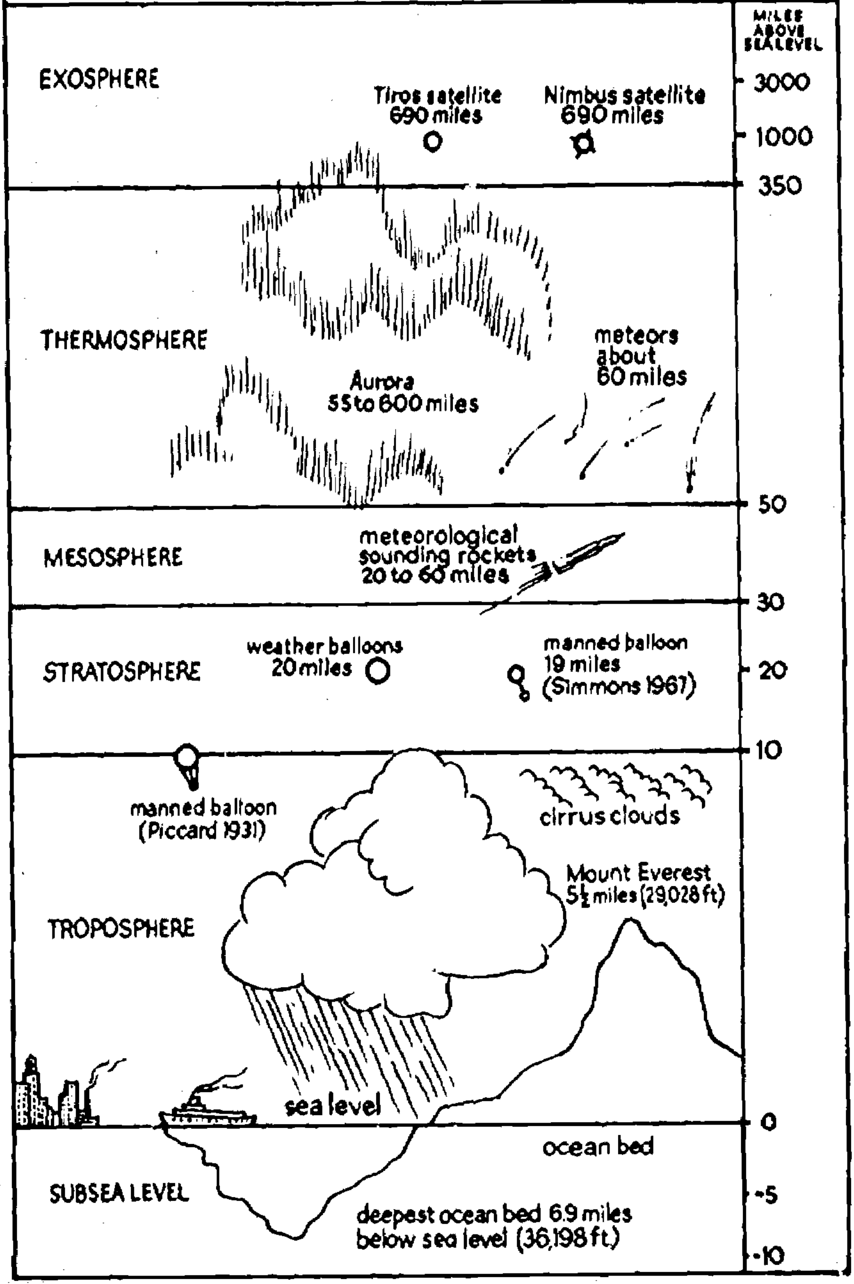


B. GOING UP IN THE ATMOSPHERE

BACKGROUND FOR THE TEACHER

Scientists have divided the atmosphere into a series of layers, one on top of the other, to point up differences in temperature, chemical composition, pressure, and other properties of the air at varying altitudes. Recent studies of the atmosphere with rockets and satellites are yielding new secrets of the earth's upper atmosphere. Further details about the atmosphere will be found in Problem 1, of this section.

A Vertical View of the Atmosphere



Earth's atmosphere extends . . . .

APPROACHES AND LEARNINGS FOR THE CHILD

In this space age of high-flying jet planes, rockets, artificial satellites, and spaceships, children hear reports of conditions in the upper atmosphere. Explorations of this region are increasing our knowledge of factors which influence weather and space travel. It is hoped that, from these investigations, weather predictions will be made with greater accuracy and for longer periods and that airplane travel will be made safer. An intriguing possibility is that some day man may know enough to be able to control the weather.

The activities developed in this section introduce children to significant facts about the atmosphere. They discover that we live at the bottom of an ocean of air; that most of this air ocean is confined to the space quite close to the earth.

From the activities suggested, children learn the following facts:

We live at the bottom of an ocean of air.

Scientists learn about the atmosphere from readings of instruments sent up in balloons, jet planes, rockets, and satellites.

Some instruments send back information to earth by means of radio and television.

The atmosphere protects us from dangerous radiation from the sun.

1. What is it like as we go up into the atmosphere?

Discuss with the children that we live in an ocean of air which extends above us for hundreds of miles. We call this ocean of air our atmosphere. Earth's gravity pulls on the atmosphere and keeps it from

. . . . a minute distance into the vastness of space.

escaping into space. The atmosphere turns with the earth. Conditions in the atmosphere change in many ways as we go up into it. Because of these differences, scientists consider the atmosphere to be divided into layers as shown in the illustration on page 173.

Discuss the fact that this ocean of air is quite close to the earth when it is compared with distances in space; that the atmosphere is really a thin layer around us, in comparison with distances from the earth to the moon or planets.

Committees of children may wish to look up information about conditions in the layers of the atmosphere. The following material includes some of the highlights which may be reported to the class and included in charts or drawings.

TROPOSPHERE. This layer is about 7 miles in height. (It varies from about 5 miles at the poles to about 11 miles at the equator.) It is the layer in which we live and where all storms, great and small, and almost all other weather conditions occur. About 90% of the atmosphere is found here, leaving only about 10% thinly scattered in the hundreds of miles above it. The temperature drops about 3½°F. for each 1000 feet as we ascend in the troposphere until the tropopause is reached. Here the temperature is about 80°F. below zero. The tropopause marks the end of the troposphere and the beginning of the stratosphere.

STRATOSPHERE. This layer extends above the troposphere to a height of about 30 miles above sea level. The air in the stratosphere is clear and cloudless except for occasional, thin ice-crystal clouds. The winds are steady without any of the up-and-down motion found in the troposphere. Flying conditions in the lower stratosphere are ideal if the occupants of the plane are protected against cold, low pressure, and the lack of oxygen. About 99% of the atmosphere is found under the 20 mile level.

A special form of oxygen, called *ozone* (O_3), is found in the upper stratosphere. Ozone absorbs most of the powerful ultraviolet radiation from the sun and in this way protects living things on earth from rays that in full strength would prove deadly. (See illustration.)

MESOSPHERE. In this layer, which extends from the top of the stratosphere to about 50 miles above the earth, the temperature falls steadily with increasing altitude, reaching minus 130°F. at its upper boundary.

THERMOSPHERE. The thermosphere contains part of a variable atmosphere layer known as the *ionosphere* which absorbs Xrays and ultraviolet rays from the sun. The ionosphere reflects back to earth radio waves, and thus makes it possible for these waves to travel around the earth. The Northern and Southern Lights are phenomena which occur in the ionosphere. In the thermosphere, which extends from 50 to 350 miles above sea level, the air is incredibly thin, being 10 million times rarer than the air at sea level.

EXOSPHERE. This layer extends from the thermosphere outward for thousands of miles. The air is so thin here that molecules can travel immense distances without hitting each other.

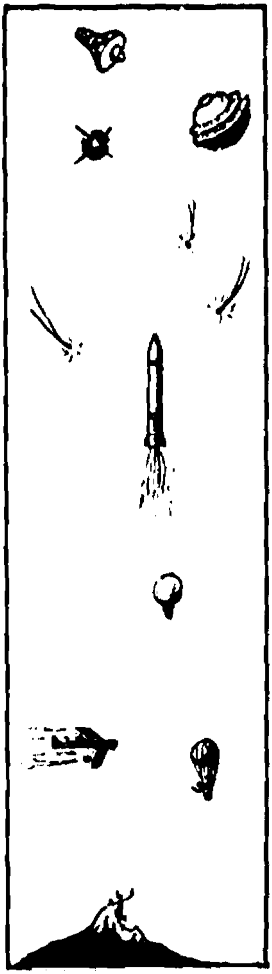
The study of the atmosphere lends itself to research in sources such as children's science books, scientific magazines, world almanacs, encyclopedias, yearbooks. Also, new discoveries about the atmosphere, reported in newspapers and other media, may be discussed.

- *For their convenience, scientists consider the atmosphere as divided into several layers.*
- *Different conditions exist in each layer.*
- *Most of the matter in the atmosphere is close to the earth.*
- *Man-made earth satellites help us learn more about the atmosphere.*

2. How do scientists learn about the atmosphere?

Scientists investigate the atmosphere in many different ways. Some methods which children may report on are suggested here. They may illustrate their reports with pictures from magazines or with their own drawings and models.

a. *Mountain climbing.* This was one of the earliest methods used to study the lower atmosphere. The children will find that the library contains interesting articles and stories about mountain climbing. In the children's reports, emphasis should be placed upon atmospheric conditions such as temperature, winds, pressure, and oxygen content, as discovered by explorers.



How man studies the atmosphere

b. *Meteors.* A meteor is observed when a chunk of metal or rock from outer space falls toward the earth. When it reaches the atmosphere, it is heated by friction with the air. It becomes red hot and shows up as a streak of light. With surveying instruments, observers can see where meteors occur. Then they can figure out at what height the streak appeared and learn more about that layer of the atmosphere.

c. *Balloons.* Periodicals occasionally carry reports about flights of manned and unmanned balloons. These carry many instruments which gather information about the atmosphere.

d. *High-flying jet planes.* Other information is gathered as airplanes fly higher and higher in the atmosphere. Reports and pictures may be brought in by students about the dangerous work of a test pilot. (The *jet streams,* belts of high-speed winds occurring at upper levels of the troposphere, were discovered by pilots flying high-altitude missions in World War II.)

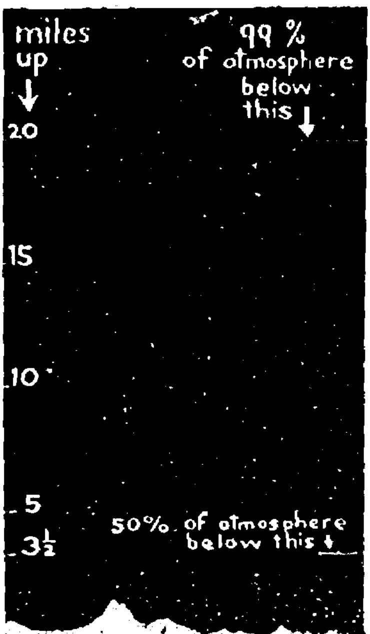
e. *Test rockets.* Unmanned rockets are sent up to probe the atmosphere. They contain instruments which measure temperature, pressure, sunlight, radiation, and meteoroid collisions. In some cases, measurements are recorded by tape recorders and cameras which are returned to earth by parachute. Sometimes, measurements are broadcast to earth and received by means of radio or television.

f. *Artificial satellites.* Measurements made by instruments in a satellite are translated into a special code and transmitted to earth as beeping radio signals. When they are received and decoded by scientists, the signals yield a wealth of information about the upper atmosphere. Some satellites contain TV cameras which send back to earth pictures of cloud coverage over large areas of the earth.

g. *Manned spaceships.* The observations, photographs, and reports of astronauts add to our knowledge of the atmosphere.

- *Scientists learn about the upper atmosphere by moving into it and by sending instruments into it.*
- *Some instruments record facts about the atmosphere and are then returned to earth by parachute.*
- *Some instruments broadcast information about the atmosphere to earth by radio or television.*

3. Why do mountain climbers carry oxygen tanks?



Ask children to discuss the difficulties of mountain climbing. Include the difficulty climbers have in breathing as they go higher and higher above sea level. As we go up, the air gets thinner and lighter. There is less of it. Mountain climbers who go very high must carry their own supply of oxygen in tanks.

Children find out and record the heights of the highest mountain peaks, such as Everest, Aconcagua, McKinley, Fujiyama, Kilimanjaro. They may find out that there are some high places in the world where people live, such as Cerro de Pasco in Peru (14,385 feet). They may find out about others. Beyond 20,000 feet above sea level, the oxygen in the air is not sufficient for human beings. On which mountains would climbers need oxygen equipment? Among those who need a special oxygen supply are balloonists and astronauts.

- *As we go up into the atmosphere, the amount of oxygen in the air decreases.*
- *To live, people need oxygen.*

4. How does a decreasing supply of oxygen affect the working of jet and rocket engines?

Engines also require oxygen to work properly. Oxygen is essential for the burning of fuel.

It might be worthwhile to point out here an important difference between jet and rocket engines.

Jet engines use the oxygen in the air for combustion of the fuel. Jet planes also make use of the air for support of the wings. Therefore, they cannot function in the extremely thin air very high above the earth.

On the other hand, rocket engines operate even in a vacuum because they carry their own oxygen for combustion of the fuel. The oxygen may be in the form of a liquid known as *lox*, or in chemicals known as oxidizing agents. Also, rockets do not have wings; they are propelled in flight by the thrust of exhaust gases. (See page 190.)

- *To operate, jet engines and rockets need oxygen.*

5. What happens to the temperature as we go up?

Children recall seeing pictures of pilots and of mountain dwellers wearing warm clothing. They may have had their own experiences in the mountains in the summertime. Discuss the fact that the temperature high on a mountain is usually cooler than the temperature at its base. (See *Science: Grade 5*, pages 132-133.)

As one goes up into the atmosphere near the earth, the temperature drops about 3½° F. for every 1,000 feet. On a warm spring day, the temperature on a high mountain may be well below freezing. The temperature continues to drop up to 7 miles above the earth (the tropopause, in our latitude), where the temperature is 80° F. below zero.

- *As we go up into the atmosphere near Earth, the temperature drops.*

6. What is meant by "flying above the weather"?

Children have probably heard this expression, since it is used in advertisements by commercial airlines. Discuss its meaning. If possible, show a photograph of a plane flying above the clouds. Ask whether any of the children have been in an airplane which flew above the clouds. Rain, lightning, snow, fog, gusty winds, and other weather conditions occur mainly in the lower part of the atmosphere. Airplanes can escape rain, fog, and storm by flying higher than the clouds, at altitudes above 20,000 feet. Advance weather information gives a pilot warning, so that he can fly above any disturbance.

Students may find out at which altitude certain airlines usually cruise and determine if this altitude is "above the weather."

- *Most weather disturbances occur at altitudes below 20,000 feet.*
- *An airplane can avoid most bad weather by flying above 20,000 feet.*

7. How does the atmosphere protect us?

Ask the class why we wear dark glasses when we are in the sunlight in the summer. Also discuss the reason for shielding our bodies from the hot sun on the beach. The children should learn that eyes and skin have to be protected from overexposure to those rays (ultraviolet) of the sun which produce sunburn and can damage delicate tissues. Point out that our atmosphere protects us from the dangers of excessive ultraviolet radiation. About 40 miles above the earth, in the stratosphere, there is a layer of ozone (a form of oxygen). This blocks out a great deal of ultraviolet radiation. Other gases in the air, water vapor, and dust particles also help prevent powerful radiations from reaching us in high enough concentrations to harm us. Cosmic rays, of which we still know very little, are also prevented from reaching us in dangerous amounts by the atmosphere. We are also protected from millions of small meteors which enter our upper atmosphere daily. These burn up in the atmosphere and reach us as a fine, invisible dust.

- *The atmosphere protects us from excessive ultraviolet radiation and from cosmic rays and meteors.*

8. How do man-made satellites help us forecast weather?

Discuss some of the weather satellites which are in orbit in the upper atmosphere. How do they obtain pictures of clouds over different parts of the world? Ask children to bring in reports and photographs. The weather satellites also send back signals about the strength of the sun's radiation through the upper atmosphere. This helps meteorologists to determine how radiations striking the earth may affect future weather.

A satellite also gathers information daily in many parts of the world. This gives a broader picture of the effects of one area's weather upon another. Even the development of a storm can be followed.

Ask children how vastly improved weather forecasting might result from a great many weather satellites televising the weather over many places on the earth at the same time. What places on the earth do not have many weather stations? (The oceans, the poles, the interiors of Africa, Australia, Asia, and South America do not have weather stations.)

- *Weather satellites can report quickly on weather conditions all over the earth.*
- *Weather satellites may make it possible to forecast weather more accurately.*

Evaluative Activities

Complete the following statements by selecting the best answer.

1. The earth's atmosphere extends
   a. for dozens of miles.
   b. for hundreds of miles.
   c. for millions of miles.
   d. for billions of miles.
   (Answer: b.)

2. As we go up about 7 miles into the atmosphere, beginning at the surface of the earth, the temperature
   a. goes up.
   b. goes down.
   c. remains the same.
   d. goes up and then down.
   (Answer: b.)

3. Hurricanes, tornadoes, cyclones, and other storms occur in the
   a. stratosphere.
   b. mesosphere.
   c. troposphere.
   d. thermosphere.
   (Answer: c.)

4. Flying conditions are good in the stratosphere because

   a. there is little up and down motion of air.
   b. it is warm.
   c. the air pressure is higher.
   d. the air is good to breathe.

   (Answer: a.)

5. As we go up in the atmosphere the pressure of the air

   a. goes up.
   b. goes down.
   c. remains the same.
   d. goes down first and then up.

   (Answer: b.)

6. Mountain climbers carry oxygen tanks because

   a. they need oxygen to start fires.
   b. oxygen makes their load lighter.
   c. the air becomes thinner as one goes up.
   d. the air becomes denser as one goes up.

   (Answer: c.)

C. FINDING OUT MORE ABOUT THE AIR AND THE ATMOSPHERE

(Enrichment Activities)

Individual children, groups, or classes showing special interest in meteorology may wish to continue their studies by means of the activities suggested below.

1. Explain why airplanes take off and land against the wind. How does the pilot know the wind direction?
2. Tell why cold water pipes sometimes "sweat" in the summer.
3. Report on the work of famous men who contributed to the science of meteorology: Galileo, Fahrenheit, Torricelli, Benjamin Franklin, Benjamin Banneker, and others.

4. How are airplanes protected from lightning?

5. How is the icing of airplane wings prevented?

6. Find out more about jet streams.

7. What are air pockets?

8. How does radar help meteorologists? How does it work?

9. What is the work of a hurricane-detection unit of the Air Corps?

0. What are the minimum conditions which close an airport to all commercial air traffic?

1. Photograph the different kinds of clouds.

2. To study upper wind direction, release helium-filled balloons into the air. Place a self-addressed postcard in a plastic bag. Also enclose a note to the finder to please return the card giving date and location. Tie bag to string of balloon.

3. What are the Northern Lights?

4. What is being done in New York City to prevent smog?

5. What is a temperature inversion? How does it retain smog over a city for days?

6. Write a report about long-range forecasting.

7. Find out about the work of the Coast Guard weather ships.

8. What is mountain sickness?

9. Set up a display of pictures and models of satellites and rockets used to explore the earth's atmosphere.

0. Using weather maps, trace the movement of warm and cold air masses as they move across the continent.

1. Write to the U.S. Weather Service, Washington, D.C. for official weather maps and cloud charts. Learn some cloud and weather phenomena symbols.

2. Visit a weather station, possibly at an airport.

3. Explain the operation of instruments which automatically record weather conditions over a long period of time, e.g., thermograph, barograph, hygrograph.

4. Explain how a maximum-minimum thermometer works.

25. Find out how to change Fahrenheit degrees on a thermometer into Celsius (centigrade) and vice versa.

26. Report on the theory and methods of cloud seeding.

27. Catch snowflakes on a dark, cold cloth. Quickly observe and draw their shapes.

BASIC SUPPLY LIST

For The Ocean of Air

Quantities specified are for groups of 2 or 4 pupils.

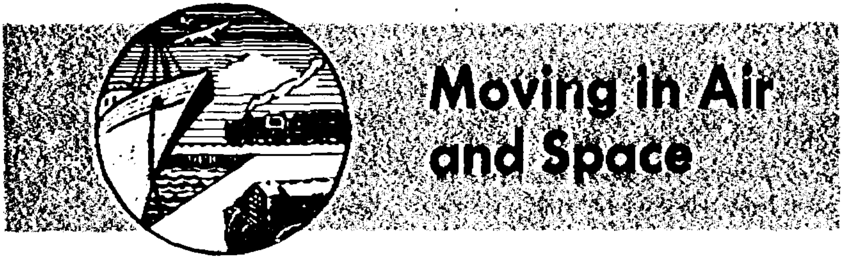
*Indicates quantity for entire class.

STOCKED SUPPLY LIST

*2 Balances, equal arms
4 Balloons
*2 Candles—teacher use only
1 Magnifying glass
Plastic tubing, 6-7" lengths
1 Can vaseline
1 Basin
*1 Package white paper
2 Paper bags
2 Plastic bags
*1 Box rubber bands
1 Pair scissors
*1 Roll scotch tape
*1 Stopwatch
1 Glass tumbler

MISCELLANEOUS

*1 Small container baking soda
1 Large size balloon
1 Handkerchief
Ice cubes
Jars, screw top lids, wide mouths
*1 Bottle limewater
*1 Box matches
*1 Box drinking straws
*1 Bottle vinegar
*1 Watch with second hand

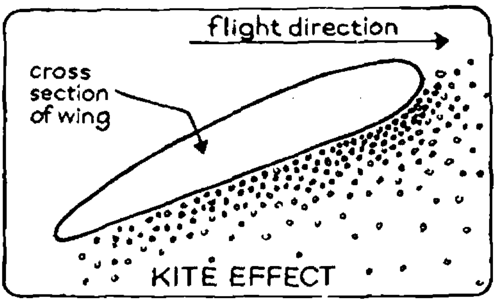


A. MOVING IN AIR

BACKGROUND FOR THE TEACHER

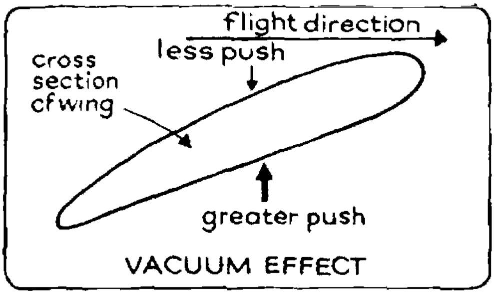
The word "airplane" has in it the two main aspects of the flight of heavier-than-air machines: "air" and "plane." Airplane flight is possible because it takes place in a real substance air. The surfaces of the wings, the "planes", are shaped so that an upward push (lift) acts on them when they move through the air.

The typical airplane wing is arched, or curved, on top and flat on bottom. As the airplane is pulled or pushed through the air, a stream of air flows across the top and bottom of the wing.



The *kite effect*. For purposes of discussion, consider first what happens when air strikes the lower surface of the wing. (See illustration.) As this surface moves forward, it squeezes together the air molecules under it and in front of it. The crowded molecules, in turn, push back against the wing. Part of the push of the molecules impedes the forward progress of the wing, but another part serves to lift the wing and with it, the airplane. A kite rises for the same reason.

The *vacuum effect.* What happens at the upper surface of the wing? Air is made up of bouncing molecules. Because of the bouncing of these molecules still air exerts a push in all directions—up, down, sidewise. At sea level this amounts to about 15 lbs. on every square inch of surface. When an airplane is at rest on the ground on a windless day, the push down on the wing is balanced by an equal push up on the bottom. But when the wing begins to move forward through the air, an interesting change occurs: the push down on the top of the wing is less than the push up on the bottom. Why?



Centuries ago, a Swiss scientist named Bernoulli found that the push exerted by a fluid *decreases* as its speed increases. This is now known as *Bernoulli's principle*. How does this explain the lifting of the airplane?

As a plane is pulled or pushed through the air by the propeller or jet action, air streams rapidly over the upper and lower surfaces of the wing. The air that flows over the curved upper surface travels a greater distance and, in addition, moves faster than the air flowing over the under surface. As a result, in accordance with Bernoulli's principle, the push on the top surface is less than the push on the bottom surface. The greater upward push lifts the wing and the plane against the pull of gravity. Since the push above the wing is *reduced* in relation to the push underneath, the effect may be called the vacuum effect.

To summarize, there are two factors which operate to give a moving wing its lift.

1. The push of air against the lower surface of the wing (the kite effect).

2. The decreased push on the upper surface of the wing relative to that on the lower surface (the vacuum effect).

The second factor is the one that produces the major part of the lift force.

APPROACHES AND LEARNINGS FOR THE CHILD

Children are interested in the many planes which fly in and out of New York City. They are familiar with many of the planes' structures and are ready to learn how these structures help the planes fly. By experimenting with strips of paper, they become familiar with the principle of lift. They find out how the plane is moved by propeller and jet action.

From the activities suggested, children learn these facts:

Propellers pull a plane through the air.

Jet action moves an airplane because the exploding gases inside the combustion chamber push harder against the front than against the rear of the chamber.

Lift is the result of the push of air on the bottom of the wing (the kite effect) and the lower push of air on the top of the wing compared to the push on the bottom of the wing (the vacuum effect).

1. What are the main parts of an airplane?

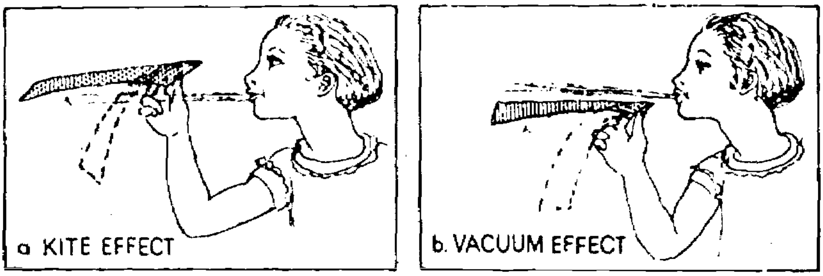
Children examine pictures and models of airplanes. They identify propellers, engines, wings, wheels, fuselages (bodies), and tails. They compare similarities and differences of various types of planes such as seaplanes, cargo planes, helicopters, military planes, jet planes. They discover the common characteristics of the parts and design which make the plane an effective air vehicle.

Prepare an exhibit of pictures and models of airplanes.

- *Many parts of an airplane are needed to help it fly.*
- *Airplanes differ in size, shape, and in the number and kinds of parts they have.*
- *All airplanes have wings and engines.*

2. What keeps an airplane up?

Lighter-than-air craft, such as balloons and dirigibles, float in the air. Airplanes are heavier than air. What force lifts the plane and supports it in the air? The answer is to be found in what happens when the wing of the plane moves through the air.



Air moving against the bottom (a) or across the top (b) of paper ("wing") makes it go up.

a. Have each child use a strip of paper, one inch by six inches, to represent a wing. Hold it so that it hangs at an angle, like an airplane wing as shown in the illustration. Now blow against the lower surface. The "wing" moves upward. This is similar to the action of wind on a kite.

When a plane moves through the air the wing hits the air, instead of the air hitting the wing as in the experiment cited. The result, however, is the same. The wing is lifted.

b. Again, holding the paper as in the illustration, have the children blow across the top. The paper is lifted again. Why? (See Background for the Teacher.)

When air moves over a curved surface, it pushes with *less* force on that surface than still air. The push on top of the paper decreases. A partial vacuum is created. Consequently, the push *up* on the bottom of the paper is greater than the push down on the top. The paper moves up.

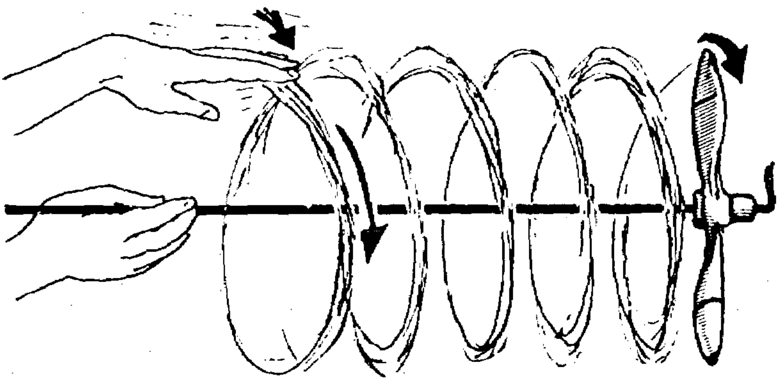
c. Look at a model or photograph of an airplane wing. Airplane wings are designed with a curved surface on top to produce the vacuum effect. The resulting lift on the wings keeps the entire plane up. (See Background for the Teacher.)

- *As a wing moves through air, a force is developed which can lift the airplane and hold it up.*
- *Lift is the result of increased push of air on the lower surface of the wing and decreased push of air on the top of the wing.*

3. How does the propeller make the airplane move forward?

In Problem 2, children learned that the wing of a plane must move through the air in order to provide lift for an airplane. The forward motion of a plane is provided either by propellers or by jet action.

Place the propeller of a model plane (these can be purchased in a hobby shop) or one that a child has whittled out of wood, on a stiff wire, such as that from a coat hanger. Strike the propeller sharply to make it spin (as shown in the illustration). (The wire should be held horizontally without a slant so that gravity does not influence its motion.)



The children will observe that the propeller advances along the wire.

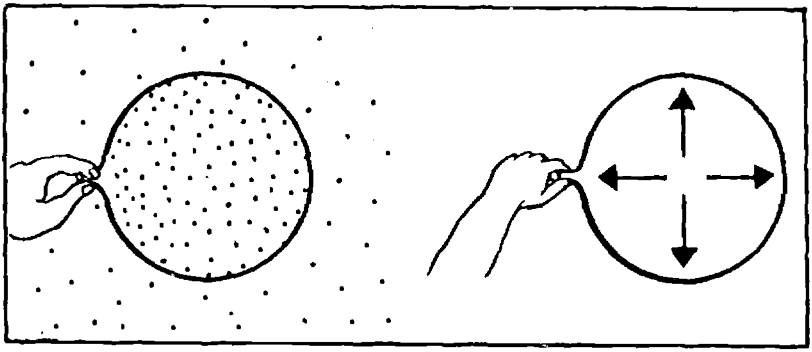
As the propeller moves forward, it pulls the entire airplane with it. This *forward motion* causes air to sweep over the wings and give lift to the airplane, as we have seen. (A common error is to think that the wind from the propellers washing backwards across the wings is responsible for lift. This is not true. Airplanes fly just as well when the propellers are located behind the wings.)

On some airplanes the direction of the propellers' spin can be reversed when the plane lands. The propeller then pushes the plane backward, helping to bring it to a stop. See what happens when the model propeller is made to spin in the opposite direction.

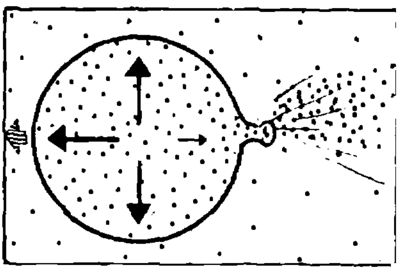
- *Propellers pull a plane through the air.*
- *As the plane is pulled forward, the air sweeping over and under the wings lifts the plane.*

4. How does jet action push a plane?

Have children demonstrate jet action by blowing up a balloon and then releasing it. They observe that the balloon moves in the opposite direction of the escaping air. Why?



When the balloon is blown up, it is packed with many molecules. The molecules bounce vigorously and push against the inside surface of the balloon. Since they push equally in all directions, the balloon does not move.

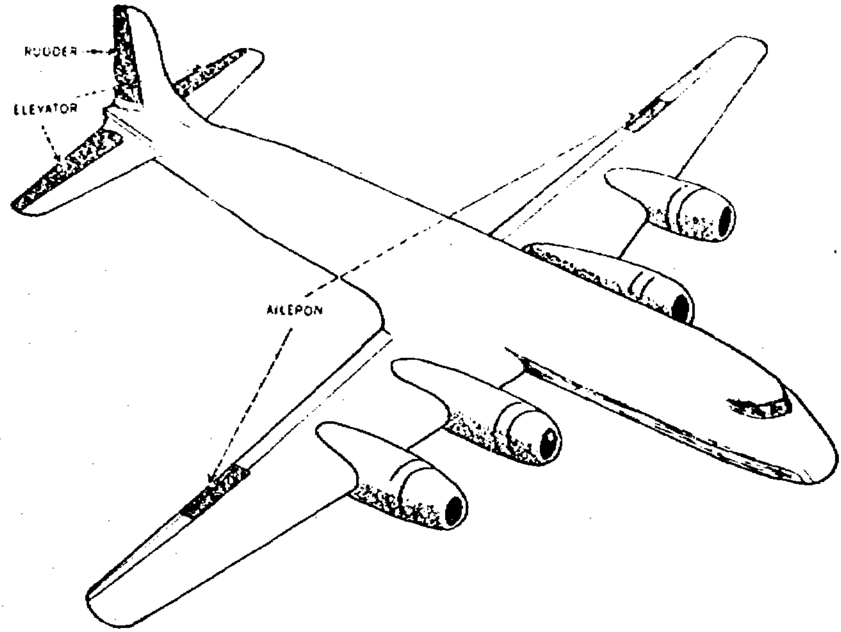


But when a balloon's nozzle is opened, molecules escape. There is less push, therefore, on that side of the balloon. Consequently, the push on the other side is greater, and the balloon moves in that direction.

In a jet engine, the explosive burning of fuel produces heated gases under great pressure. As a result, large numbers of molecules beat vigorously against the inner walls of the combustion chamber. Since the rear end is open, the molecules rush out. They have no wall here to beat on. Consequently, there is less force acting on that end than on the front end of the plane. The plane is pushed forward.

- *Jet action results from the greater push of gas against the closed front end of the engine than against the open back end.*

5. What parts of the plane control its position in the air?

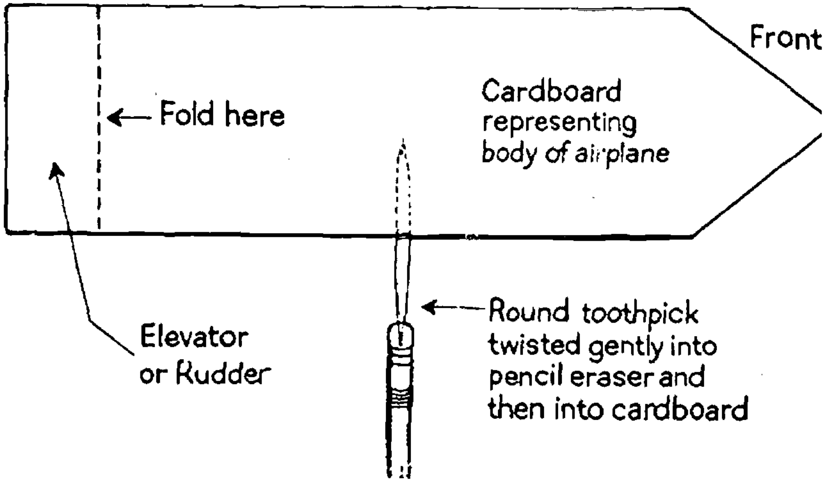


Ask the children to bring to class model planes, gliders, and photographs of planes. Ask them to identify the elevator, rudder, and ailerons. These are called the "control surfaces" of the plane. In the problems which follow, they will see how each of these control surfaces helps the plane change its position in the air. If it is possible, visit an airport to see the control surfaces on a real plane.

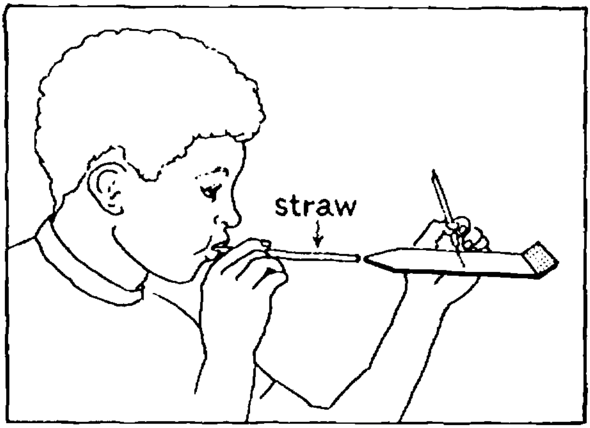
- *The elevator, rudder, and ailerons control the position of an airplane in the air.*

6. What makes an airplane climb?

Have each child make a model of an elevator (see illustration, page 192). Using a straw, aim a steady stream of air at the arrow. (Hold the pencil loosely.) What happens when the elevator is up? (The



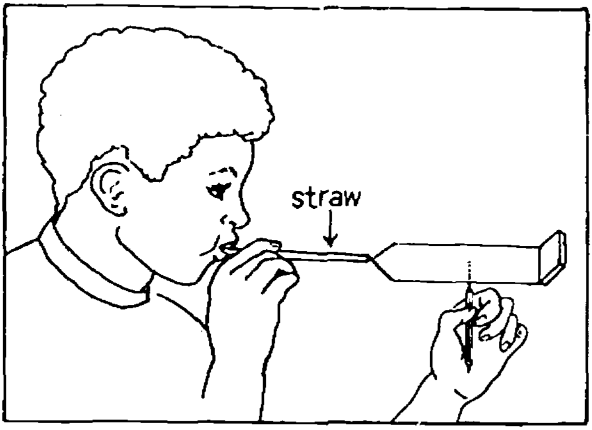
arrow points up). What happens when the elevator is down? (The arro points down.) What happens when we blow harder? What happe when the elevator is raised or lowered a bit?



In flight how does the elevator control the position of the plane? (A striking the upturned elevator causes the tail of the plane to be push down, thus causing the nose to tilt up. When the elevator is down, t opposite result occurs.)

In a real airplane, merely raising the elevators makes the plane go u for a short time only, since it loses speed like a bicycle climbing a ste hill. The chief job of the elevators is to change the *position* of the pla in the air. To climb from level flight it is also necessary to increase engine speed. As a result, there is more lift on the wings (see Problem 2) and the plane rises.

- *The elevator of a plane tilts the plane up or down.*
- *When the elevator of a plane is turned up and the propeller speed is increased, a plane goes up.*
- *When the elevator is turned down, the plane goes down.*



7. How does an airplane turn?

a. What does the rudder do?

Use the same model as was used for the demonstration of the elevator, but now hold the pencil in a vertical position loosely as shown in the illustration. Face the arrow head and bend the rudder to the right. Blow directly at the arrow point. What happens? (The arrow head moves to the right.) What happens when the rudder is bent to the left? (The arrow head moves to the left.) What happens when we blow harder? What happens when we vary the angle at which the rudder is bent?

In flight, the air striking the rudder causes the tail of the plane to swing to the left or right. Consequently, the nose of the plane changes direction.

The turning of the rudder, by itself however, does not make the plane fly in a new direction. It merely *points* the plane in a new direction. To change direction of flight, rudder and aileron action must be combined.

b. What do ailerons do?

Have each child make a model of a wing equipped with two ailerons, as shown in the illustration. Rest the pencil on a book, with the "wing" in a horizontal position. Give each child two straws so that he can blow at the left and right sides of the back of the wing at the same time. The two ailerons are always tilted in the opposite direction to each other. Adjust the ailerons so that the right aileron is down and the left aileron is up. Blow on the leading edge of the wing as shown in the illustration. Children note that the wing tilts to the left. Reverse the position of the ailerons and blow again. The wing now tilts to the right.

How does the tilting of the wing influence the plane? We learned in Problem 2 how lift is exerted upward on the wing. To be more exact, lift is perpendicular to the wing.

If the wing is tilted to the left, part of the lift is exerted to the left and the plane turns left. The opposite is true if the wing is tilted to the right. The rudder helps in turning the plane to the left or right.

In other words, turning is done by tilting the plane so that part of the lift of the wings is used to pull the plane to the left or right. Trying to turn by using the rudder alone is like trying to make a sharp turn in an auto while traveling rapidly on an icy road. The car may point in the new direction, but it continues skidding off in the original one.

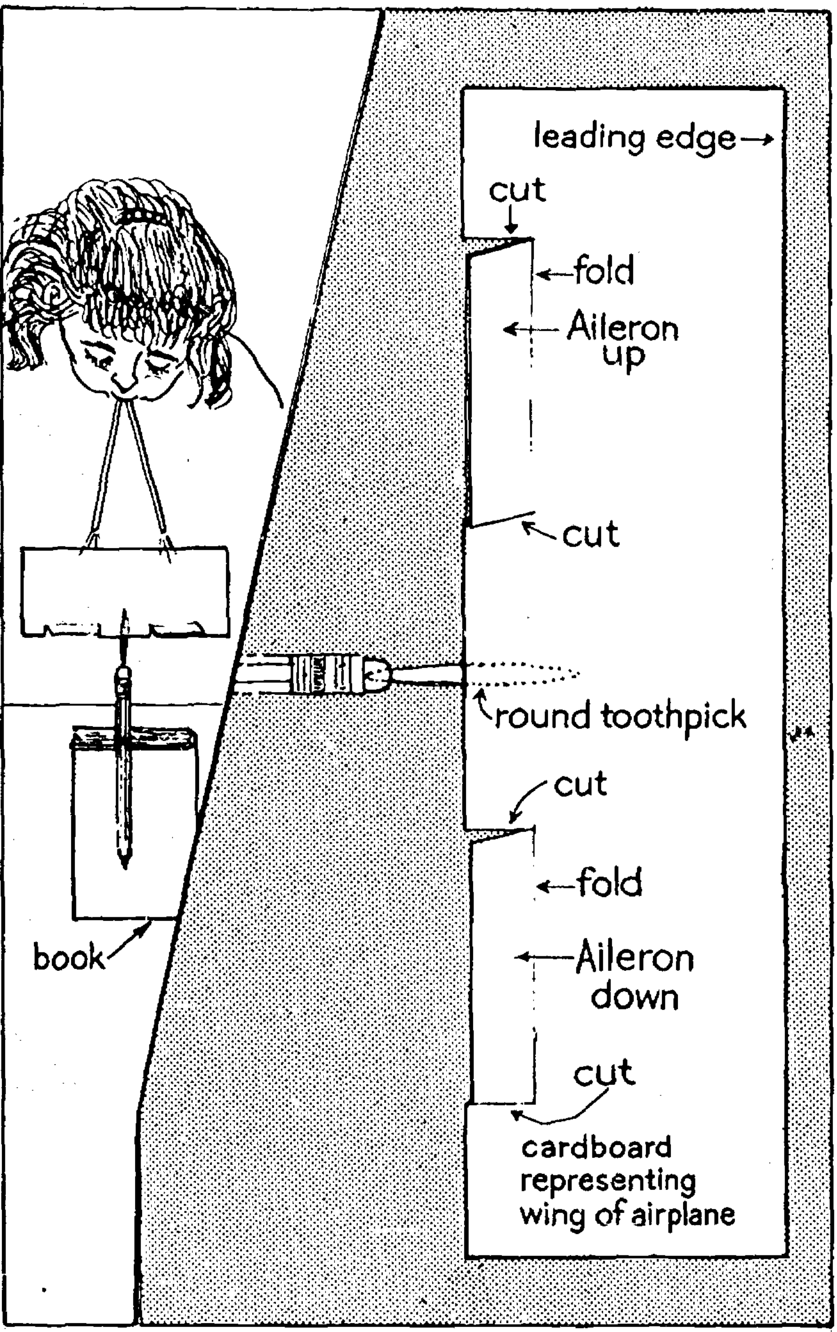
- *An airplane is made to move in a new direction by moving the ailerons.*
- *Ailerons always move in the opposite direction.*
- *The rudder helps steer a plane.*

Evaluative Activities

Complete each of the following statements by selecting the best answer.

1. The propeller's purpose is to
   a. blow air over the wings.
   b. pull the plane through the air.
   c. move the air away from the plane.
   d. cool the plane.

(Answer: b.)


leading edge
cut
fold
Aileron up
cut
round toothpick
cut
fold
Aileron down
cut
cardboard representing wing of airplane
book

2. The wing of an airplane is shaped to make air move over the top
   a. faster than over the bottom.
   b. more slowly than over the bottom.
   c. at the same speed as over the bottom.

(Answer: a.)

3. Elevators on a plane are used to help
   a. steer the plane to the right or to the left.
   b. tilt the plane up or down.
   c. tilt the plane from side to side.

(Answer: b.)

5. The push of air on top of the wing of a plane in flight is
   a. same as b. greater than c. less than
   the push of air on the bottom of the wing.

(Answer: c.)

6. To change the path of a plane to the left or right, a pilot usually moves the
   a. rudder.
   b. elevators.
   c. ailerons and rudder.
   d. ailerons.

(Answer: c.)

7. An airplane cannot fly around the moon because
   a. gravity is less than on earth.
   b. gravity is more than on earth.
   c. the temperature is too hot or too cold.
   d. there is no air.

(Answer: d.)

8. A jet plane moves
   a. in the same direction as that of escaping gases.
   b. in the opposite direction of the escaping gases.
   c. when the gases stop escaping.

(Answer: b.)

B. FINDING OUT MORE ABOUT MOVING IN AIR

(Enrichment Activities)

Interested pupils may wish to conduct some of the following projects. They should be encouraged to report their findings to the class.

1. Investigate the action of propellers of different shapes.
2. Construct a wind tunnel to test model planes and gliders. How can lift be measured?
3. Make a demonstration to show the effect of increased speed on lift of a model of an airplane wing.
4. Find out about the supersonic plane. How is it different from other planes? What special problems have arisen because of the sonic boom?
5. How does the helicopter work? What gives it lift? Find out about the various uses of helicopters. When are they more useful than other types of aircraft?
6. Find out about aids to navigation for modern jet planes.
7. How is a new design for an airplane developed?
8. What vocational opportunities are available in aviation? How can one become a pilot, a hostess, a mechanic?
9. Consult the Civil Aeronautics Administration for its role in regulating aviation. Make a chart of air traffic safety rules.
10. How is radio communication used in modern aircraft?
11. Find out and report about the rocket plane.
12. How has weather forecasting influenced aviation?
13. Make a kite and fly it. What flight principles are involved in its operation?
14. How is the jet age affecting our environment with regard to air pollution, noise, city traffic?
15. Make paper gliders and see how they work outdoors in the wind and in a room where there is no wind.
16. Invite a pilot to explain about flying a plane.

17. Prepare a bulletin board illustrating the history of aviation.

18. Make a scrapbook of current events in aviation.

19. A special mobile program on aviation, Flight Plan: The Classroom, is available by calling the Aviation Development Council at La Guardia Airport. The program includes a series of slides entitled *History of Aviation*, a description of preflight routines at the airport, and a demonstration explaining thrust, lift, and the use of the control surfaces. Pilots from the New York area have volunteered their time to make these presentations.

C. MOVING IN SPACE

BACKGROUND FOR THE TEACHER

Space travel is based upon principles that were formulated by Sir Isaac Newton some 300 years ago. The thrust produced by a jet engine, the influence of gravity, the path of a satellite in orbit, the nature of weightlessness, and the forces (g's) experienced by an astronaut are explained by Newton's laws of motion.

The teacher is referred to each of the problems which follow for further background in this area.

APPROACHES AND LEARNINGS FOR THE CHILD

Children are aware that they live in the age of space exploration. Apollo missions and the landings on the moon fill them with wonder. They want to know about rockets, satellites, spaceships, and weightlessness. They are interested in conducting experiments and demonstrations which illuminate the principles of space travel.

From the activities suggested, children learn these facts:

Rockets have made space travel possible.

To stay in orbit, a satellite must move at the right speed.

Satellites maintain their speed in orbits high above the earth because there is no air there to slow them.

On its way to the moon, a spaceship is slowed by the pull of earth's gravity.

1. What spaceships have you seen blasting off?

This question is an invitation to the children to pool their experiences and backgrounds with respect to the launching of space vehicles of all kinds. This question may also lead to reports by the students, based on magazine articles and books they read and television programs they see. It may also lead to the construction of models, charts, and drawings depicting current space missions. Most important of all, discussion may lead children to ask questions about the "hows and whys" of space travel, such as these:

- How is a spaceship lifted off its pad?
- How does gravity affect space flight?
- Why are rocket engines used in space travel?
- Why do space rockets use several stages?
- How do satellites get into orbit around the earth?
- What keeps a satellite in orbit?
- How do spaceships escape from the earth?
- What is weightlessness?

Some of these questions are taken up in the problems which follow.

2. How is a spaceship lifted off its pad?

Review the discussion of jet propulsion in Topic A, Problem 5. Jet action, which pushes a plane through the air, also supplies the thrust to lift a spaceship from its pad and into space.

Focus attention on two aspects of space launchings:

a. The *total weight* of the ship, including what it is carrying.

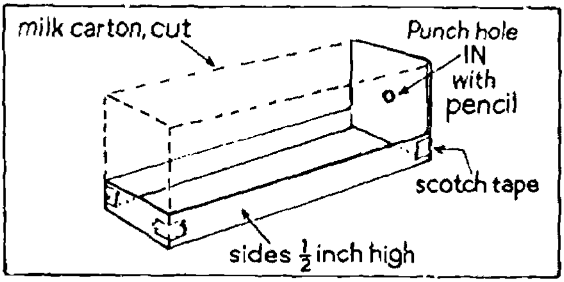
b. The *thrust* or push necessary to lift the weight.

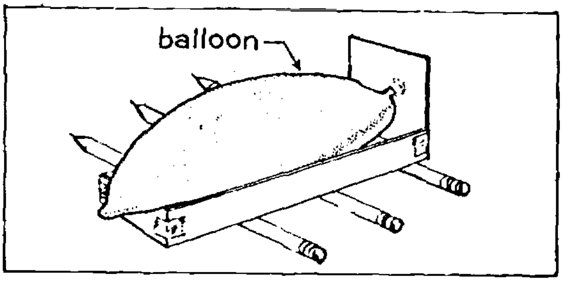
It is useful at this point to have children experiment freely with a jet-propelled device which permits them to:

a. Vary the weight to be carried.

b. Vary the amount of thrust.

Such a device is provided in a "jet sled" constructed quickly by each pupil from a milk carton, balloon, and pencil, as shown below.





The sled does not lift into the air, but it does roll or slide on a surface such as a floor or table. Its effectiveness is judged and measured by the distance it rolls. The weight to be carried may be made of a number of standard small units, such as wooden beads, paper clips, or coins.

Ask the pupils to suggest experiments to conduct with the space sled. These may include the following:

a. Vary the *weight* carried (2, 4, 8, or more beads).
b. Blow up the balloon to various *sizes* (full, half full).

In the course of their experimentation pupils may find that in addition to weight carried and balloon size, additional factors which influence the performance of the jet sled include:

a. The nature of the surface on which the sled is sliding.
b. The condition of the neck of the balloon. (Is it sticky? Does the air flow out rapidly?)
c. The presence or absence of rollers (pencils).

The discussion that follows the various trial runs should develop the understanding that in a real spaceship the gases that are ejected are produced by burning large amounts of fuel.

- *The distance a jet sled travels is determined by*
    a. *The amount of air released by the balloon.*
    b. *The speed at which the air is released.*
    c. *The weight it carries.*
- *A successful launching of a spaceship from its pad depends on the release of enough gas, moving at sufficient speed to exert a force greater than the pull of gravity on the ship.*

3. How does gravity affect space flight?

Drop an object from your hand. What happens to it? (It falls to the floor.) In what direction does it fall? (It falls down.) Show pupils a globe. What does "down" mean with reference to the earth? (It means toward the center of the earth.) Why does the object fall down or move up rather than stay where it is?

This question should begin a discussion of the nature of gravity. The following ideas are significant:

a. All bodies from the largest star in the universe to the smallest particle attract each other with what is called a gravitational force.

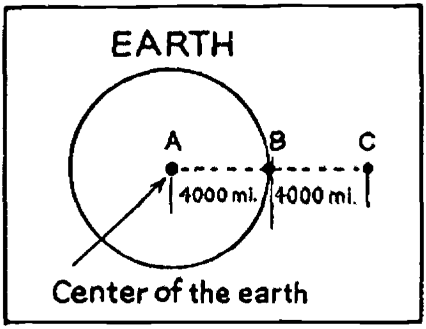
b. The strength of the gravitational force between two bodies depends on

   (1) The amount of material in them.

   (2) The distance between them. (The attraction decreases as the distance increases.)

The gravitational attraction between the earth and an object decreases as its distance from the earth increases. Distances are measured from the *center* of the earth. For example, a body 4,000 miles up is twice as far from the center of the earth as one on the surface.

The gravitational pull of the earth is ¼ as great at C as it is at B.



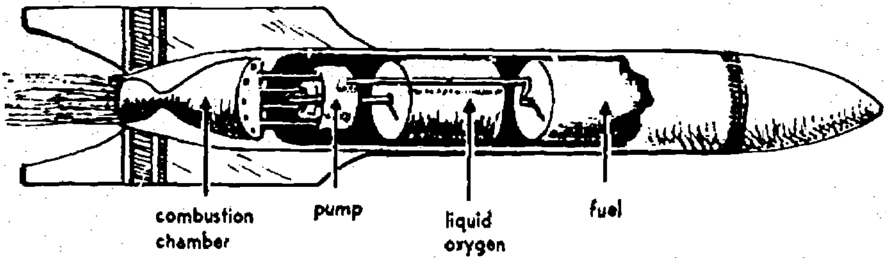
On a trip from the earth to the moon, the gravitational attraction of both the earth and the moon will influence a spaceship. (See Problem 8).

- *Gravity affects the flight of spaceships.*
- *The strength of gravity between 2 bodies depends on amount of material in them and the distances between them.*
- *As a body moves away from the earth, the gravitational attraction between the body and the earth decreases.*

4. Why are rocket engines used in space travel?

Ask children to recall from Grade 5 the requirements for burning: fuel, oxygen, and enough heat to ignite the fuel.

All air and space vehicles, that is, propeller planes, jet planes, and spaceships, burn fuel to supply the energy to make them go.



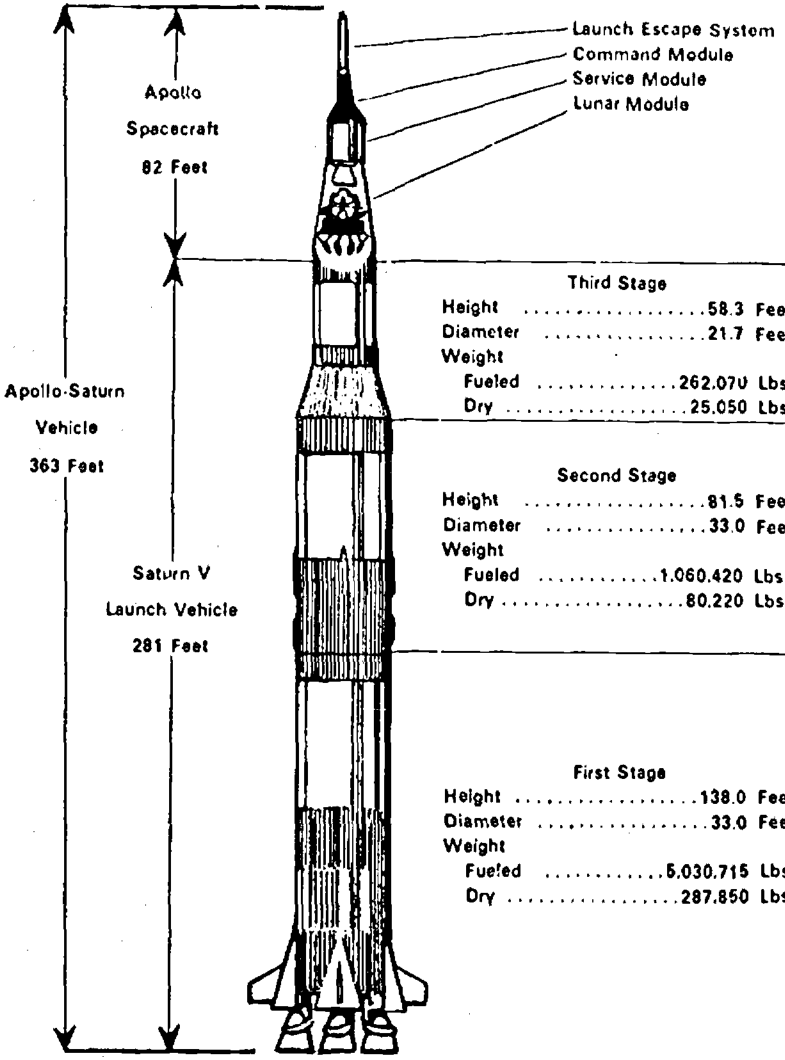
Airplane engines take in oxygen from the air around them. A rocket engine, however, carries its own supply of oxygen (see illustration). Why must spaceships use rocket engines? (Ninety-nine percent of the air is contained within the first 20 miles above the surface of the earth. Spaceships travel thousands of miles through airless space.)

- *Spaceships travel through airless space.*
- *Rocket engines are needed for space flight because they carry their own supply of oxygen.*

5. Why do space rockets use several stages?

Children know from seeing space launchings on TV that the rocket which propels the space vehicle into orbit or on a space voyage is made of 2, 3, or more stages. As each stage burns its fuel, it is separated from the space vehicle.

APOLLO 12 – THE FACTS AND FIGURES



Third Stage

Height	58.3 Feet
Diameter	21.7 Feet
Weight	
Fueled	262,070 Lbs.
Dry	25,050 Lbs.

Second Stage

Height	81.5 Feet
Diameter	33.0 Feet
Weight	
Fueled	1,060,420 Lbs.
Dry	80,220 Lbs.

First Stage

Height	138.0 Feet
Diameter	33.0 Feet
Weight	
Fueled	5,030,715 Lbs.
Dry	287,850 Lbs.

The Apollo-Saturn: Spacetrain of Three Powerful Locomotives and One Passenger Car

Ask pupils to answer the questions about Apollo 12 which follow:

a. Which stage is heaviest? (The first stage is heaviest.)

b. What happens to the spaceship while the first stage is burning its fuel? (The spaceship is lifted off the pad and travels faster and faster.)

c. How much weight is lost by the burning of the fuel of the first stage? (5,030,715 pounds are lost.)

d. What advantage is there in dropping the empty stage? (The spaceship gets rid of another 287,850 lbs. and is able to go faster.)

e. What does the second stage do when the first burns out? (It begins to burn and adds speed.)

f. Why is the empty second stage dropped? (It is dropped for the same reason as the first stage.)

g. What does the third stage do when the second burns out? (It burns its fuel and adds speed to the spaceship.)

h. Why is the third stage dropped? (It is dropped for the same reason as the first and second stages.)

Multistage rockets are used in spaceships because

a. Each stage adds to the speed given by the previous stage.

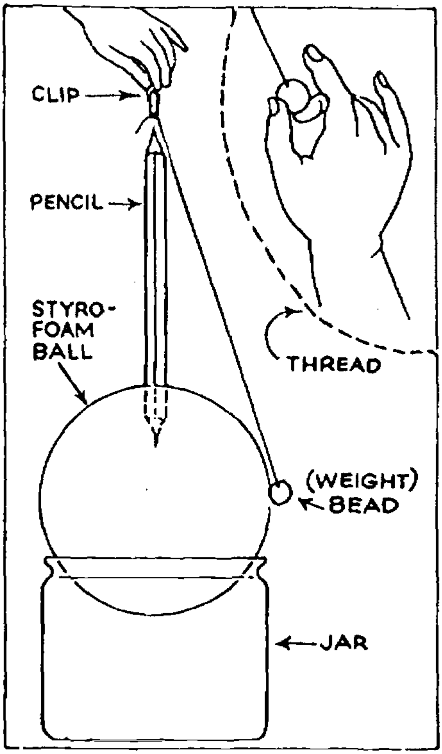
b. Dropping one stage after burnout gives the next stages less dead weight to carry.

6. How do satellites get into orbit around the earth?

In addition to hoisting a spaceship away from the earth at faster and faster speeds, rocket engines used for earth satellites perform one other job. They direct the satellite into a *path* that makes it possible for the satellite to orbit the earth. How is this done?

The following demonstration requires only a string, a small weight (such as a wooden bead) attached to one end of it, a paper clip attached to the other end, and a styrofoam ball, as shown in the illustration. The weight represents the satellite, and the ball represents the earth. Hold the clip in one hand directly over the center of the ball so that the weight rests against the "equator" of the ball. The pencil is pushed partway into the ball and towards its center. The ball is positioned so that the pencil is vertical and points directly over the center of the ball.

Ask the pupils to try to launch the "satellite" into orbit around the earth by tapping it with a finger from its resting position. They may tap it in any direction, but they must start from the resting position against the "earth". They are not allowed to maneuver it with the clip which is held directly over the point of the pencil. They find that no matter what they do, the weight does not make a complete orbit. It always returns to the "earth". The best that it can do is to return to the place where it was launched.



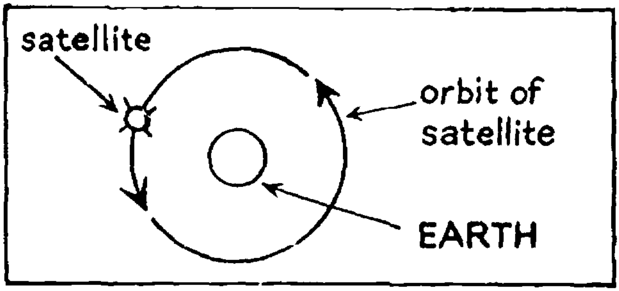
Then how can it be launched into orbit? What must be done differently? Again, no maneuvering with the clip is permitted; it must be held over the center of the ball and not moved. But the pupils are allowed to *start* the satellite from wherever they please. They find that if they hold it away from the ball and push it parallel to its surface, they can effect a successful launching of two, three, or more orbits. The position shown in the diagram is an effective one.

How hard do they have to push the weight to get into orbit? If they give it a slight push, it will not complete one orbit; it will fall back to earth. If they snap it too hard, it will go far out but hit the earth again. A moderate push is the most successful.

- *To go into orbit a satellite must travel parallel to the earth's surface and go at the right speed.*

7. What keeps a satellite in orbit?

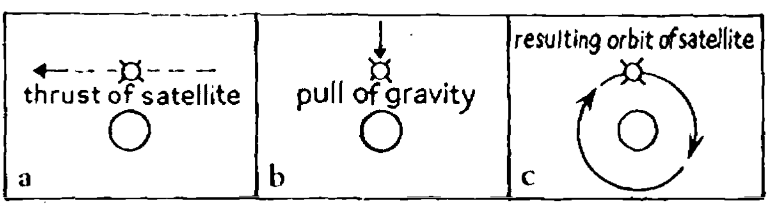
Some of the satellites orbiting the earth today will remain in orbit for thousands of years. What keeps them moving in orbit? There are two parts to this question.



a. What keeps the satellite moving?

A satellite which orbits at a distance of 200 miles from the earth moves at the speed of 5 miles a second. Why does it keep going at this speed after the last bit of fuel is burned up? On earth, moving objects, such as cars, trains, ships stop moving unless they are continuously propelled by some force. Propulsion is necessary because these moving objects are constantly opposing the force of friction that results from their contact with the ground, water, air, and so on. Without friction, a moving car could coast forever with its motor turned off. At an altitude of 100 or more miles above the earth the effect of the atmosphere is negligible, so that there is practically nothing to slow down the speed of satellites.

b. Why do satellites move in a curved path around the earth?



At any moment an earth satellite 200 miles up moves at the speed of about 5 miles per second in a direction parallel to the surface of the earth beneath it. What prevents it from flying off into space? What force is acting on the satellite at all times? (Earth's gravitational attraction acts on the satellite.)

Recall the experiment with the string, the weight, and the ball (Problem 6). Although the weight was pushed or flicked in a direction parallel to the ball, it made a circular orbit. Why? (At the same time that it was moving away from the ball, the string pulled on the weight.) What would happen if you flicked the ball and at the same time released the string? (The ball would fly away from the "earth".) The curved orbit of the weight, then, is the result of both the pull of the string and the push given to it by the finger.

In real satellites what corresponds to the pull of the string? (The pull of the earth's gravity corresponds to the pull of the string.)

- *A satellite in orbit does not require an engine to move it. It keeps going because there is nothing to slow it down.*
- *A satellite's path in orbit is determined by the original direction given to it by the rockets and by the gravitational attraction of the earth.*

8. How do spaceships escape from the earth?

Recalling the Apollo space missions, the spaceships first went into earth orbit at about 5 miles per second or about 18,000 miles an hour. After swinging around the earth, jets of the third stage increased the speed of the spaceship to 7 miles per second or about 25,000 miles per hour which then made the spaceship streak off to the moon. The third stage then diminished and the spaceship coasted towards the moon.

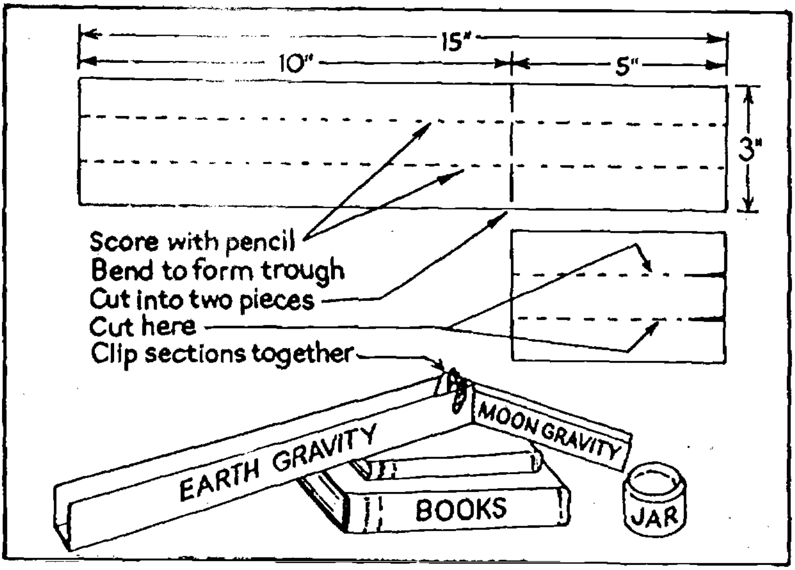
Seven miles per second is the *escape velocity* needed for an object to escape from the earth. If an object at or near the earth attains that speed, it can escape from the earth even if all of its fuel is used up.

A way of representing the trip to the moon is shown in the illustration on page 208.

The long trough *represents* the earth's gravity.

The short trough *represents* the moon's gravity.

The marble *represents* the spaceship.



If the marble is moved with the right force, it will coast past the dividing line and then fall into the "moon", represented by the cup. If too much force is used, the marble will skip over and beyond the "moon". If too little force is used, it will fall back to "earth".

Will it take as much force to launch a ball from the moon to the earth? (No.) Why? (There is less gravity to overcome.) This demonstration should *not* lead students to think that the earth's gravity *ends* and the moon's *begins* at a given point. Both are present everywhere. The troughs merely show where the gravity of one is *stronger* than that of the other.

- *To escape from the earth a spaceship must acquire a speed of 7 miles per second or 25,000 miles per hour.*
- *On its way into space a spaceship slows down after burnout because the earth's gravity continues to pull it.*
- *On a trip to the moon a spaceship speeds up when it passes a point about ⅞ of the way to the moon. At this point the moon's gravity makes the ship go faster and faster.*
- *To use the least fuel a moon-bound spaceship should be pushed hard enough to reach the point where the moon's gravity becomes stronger than the earth's gravity. The ship then "falls" the rest of the way to the moon.*

Evaluative Activities

Complete each of the following statements by selecting the best answer.

1. Rockets are the only engines that can be used in flights through space because

   a. they move very fast.

   b. they are small and compact.

   c. they carry their own supply of oxygen.

   (Answer: c.)

2. Satellites maintain their speed in orbits high above the earth because

   a. they have enough fuel to keep them going.

   b. the engine prevents them from going too fast.

   c. there is no air there to slow them down.

   (Answer: c.)

3. As a spaceship moves away from the earth, the earth's gravity

   a. slows it down.

   b. speeds it up.

   c. does not affect its speed.

   (Answer: a.)

4. As a spaceship approaches the moon, the moon's gravity

   a. slows it down.

   b. speeds it up.

   c. does not affect its speed.

   (Answer: b.)

5. In a moon landing, parachutes are not used because

   a. they are too big to carry on the long trip to the moon.

   b. there is no water on the moon for a soft landing.

   c. there is no air on the moon to slow down the parachute.

   (Answer: c.)

D. FINDING OUT MORE ABOUT MOVING IN SPACE

(Enrichment Activities)

Interested pupils may wish to conduct some of the following projects. They should be encouraged to report their findings to the class.

1. Watch the newspapers for the time to observe the visible satellites. Try to observe a satellite for a number of evenings.
2. Report on current space missions.
3. Read and report on the various satellites now circling the earth. What jobs do they perform?
4. Report on the problems faced by astronauts in landing, walking, and staying alive on the moon. How did they meet these problems?
5. Visit the Hayden Planetarium in Manhattan, the American Museum of Natural History in Manhattan, and the Hall of Science in Queens to view space exhibits and shows. Tell your class about these visits.
6. Report on the kinds of fuels used in spaceships.
7. What is weightlessness? How can it be demonstrated?

BASIC SUPPLY LIST

For Moving in Air and Space

Quantities specified are for groups of 2 or 4 pupils.

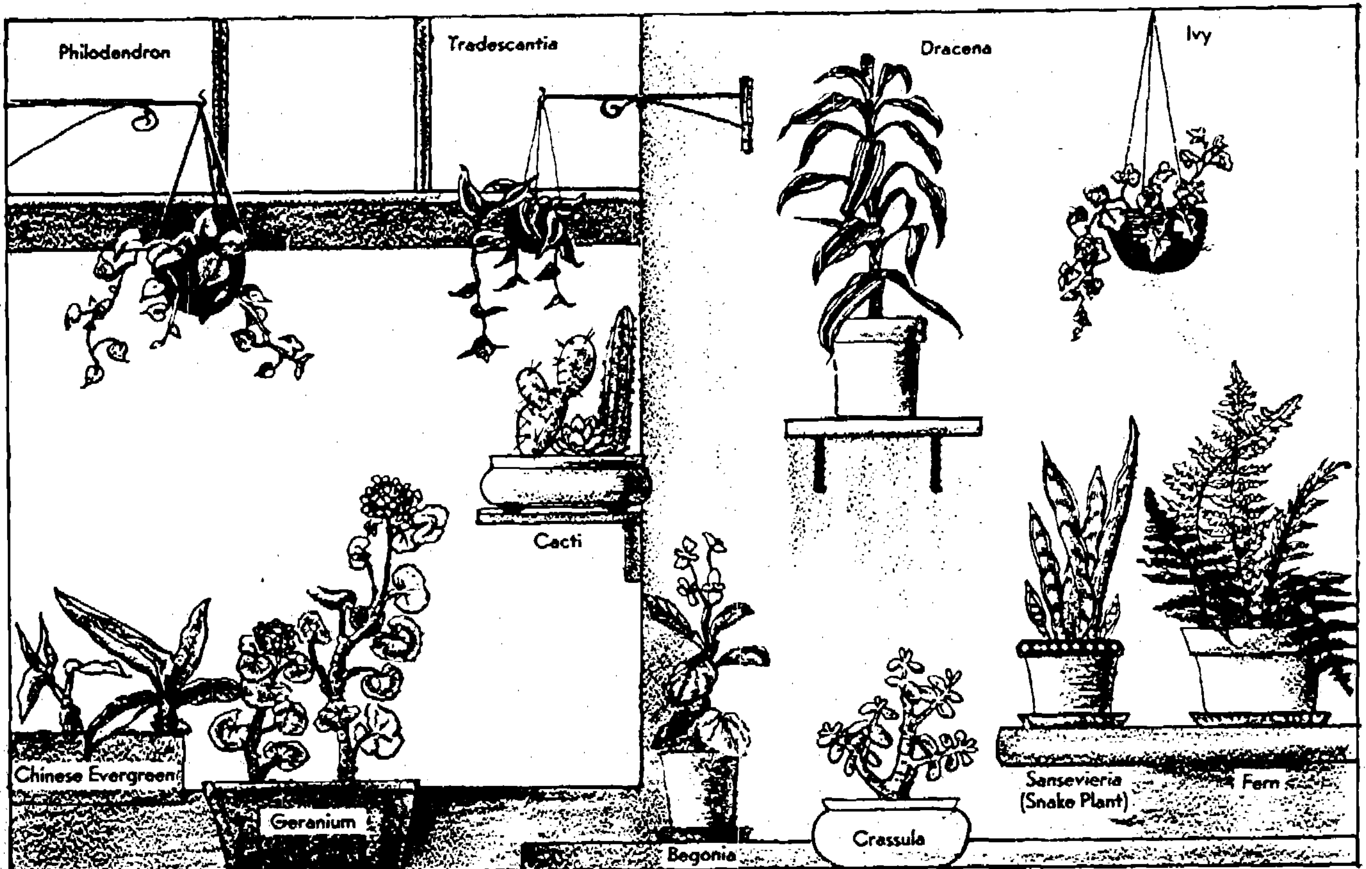
*Indicates quantity for entire class.

STOCKED SUPPLY LIST

1 Ball, styrofoam, 3" diameter
*3 Packages balloons
*1 Dozen bottles, wide mouth, 8 oz.
*1 Dozen funnels
*1 Globe
10 Wooden beads
*2 Packages pins
10 Pairs scissors
1 Pair pliers
*1 Box paper clips
1 Hammer
*5 Sheets oak tag
*2 Packages round pencils without eraser tops
*1 Ball string
*1 Ball twine
1 Screwdriver

MISCELLANEOUS

*12 Ping-pong balls
Coins
1 Cup
1 Milk carton
1 Small electric fan
*6 Wire coat hangers
Marbles
Small plastic propellers
*2 Boxes of drinking straws
15 Empty spools of thread


Philodendron
Tradescantia
Dracena
Ivy
Cacti
Chinese Evergreen
Geranium
Begonia
Crassula
Sansevieria
(Snake Plant)
Fern

A "Green Thumb" in the Classroom

The classroom is home for about one half of the waking hours of both teachers and students. It becomes more cheery and colorful with the addition of plants which children can care for. Teachers and children can acquire "green thumbs" by putting these plants into soil. Where there are different kinds of plants in a room, there will be opportunities to discuss them and care for them. Children should be encouraged to observe the plants, report on their growth, and try to find the best ways of caring for each kind.

The hardy plants used most often in the classroom are: geranium, ever-blooming begonia, coleus, tradescantia, philodendron, pothos, English ivy, grape ivy, crassula, ferns, cactus, snake plant, nephthytis, Chinese evergreen, dracaena, pick-a-back, peperomia.

Children can also grow sweet potatoes, beet and carrot tops, seeds of avocados, squash, watermelons, pumpkins, grapefruit, lemons, oranges, apples, peaches, cherries, lima beans, and sunflowers. See illustration on page 183 in *Science: Grades K-2*.

Bulb growing, of course, is a well-established custom in schools. See illustration on page 184 in *Science: Grades K-2*.

In the spring, marigold, nasturtium, or petunia seeds will produce attractive and hardy plants which can be grown in school.

Covered terraria can be made with gravel and soil in a fish tank or bowl or a large mustard jar obtained from the neighborhood delicatessen. See illustration on page 184 in *Science: Grades K-2*.

Plants will grow successfully if they have:

Sufficient water. Plants should be watered only when the soil feels dry. However, when adding water, soak the soil thoroughly.

Good drainage. The pot or box should have holes in the bottom to allow excess water to escape. (The roots of a plant require air.

Water which remains may prevent air from entering the soil.) Saucers or aluminum pie plates under flower pots will protect the woodwork and catch drained water. One can water plants by adding water to the saucer until the top of the soil is moist. (Empty the saucer of any water which remains after the soil is moist.)

Suitable temperature. Plants should not be placed on hot radiators or in hot or cold drafts. Protect plants during cold weekends.

Proper light conditions. Experience is the best teacher. A geranium, for example, needs a good deal of sunlight. Cactus also thrives in sunlight. Begonias and some ferns, on the other hand, should not be kept in direct sunlight for many hours at a time. Most plants will grow with only a few hours of sunlight. Many will need only the light from the sky. No green plant, however, will do well in a dark area.

Good soil. While each plant has its own soil requirements, any good garden or potting soil will usually be satisfactory. The addition of sand will make the soil more porous. If the soil dries too quickly, peat moss or humus can be added. Commercial fertilizer may be used, but only according to the directions on the package.

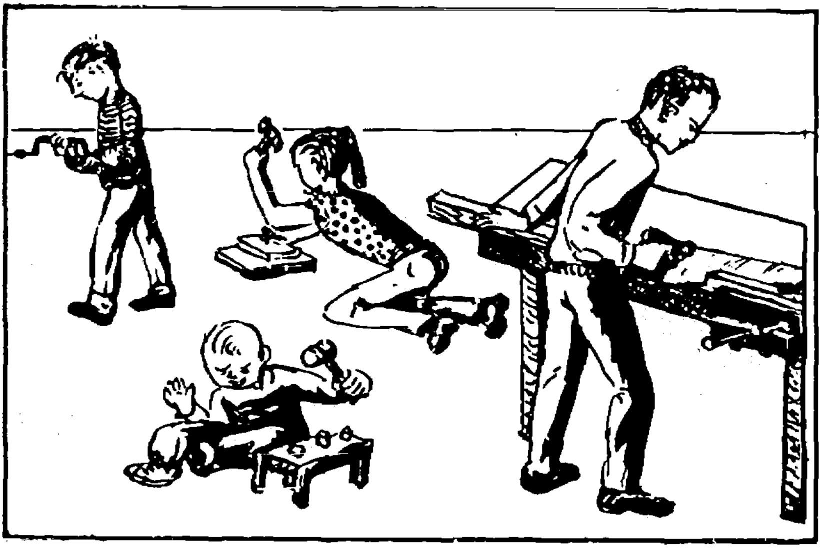
Other care. Leaves should be showered or washed with a sponge from time to time. Insect pests can be removed by washing leaves.

NOTE: When transplanting, take care to avoid injuring the roots.

Children may interview a school or neighborhood person who has had notable success in growing plants and report to the class on the advice obtained. Further information on household plants can be found in any library.

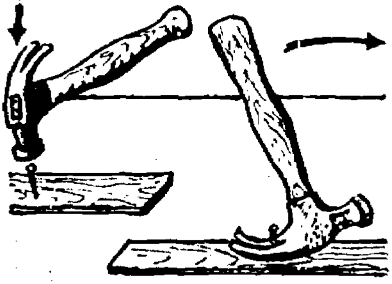
Tools We Use

In the course of constructing models and performing experiments in science, children use common tools such as hammers, screwdrivers, pliers, and saws. The teacher may use the opportunity that is thus presented for improving children's skill and understanding in the use of tools. The following supplementary material is intended to help children look more closely at tools, and to discover how they work and how to use them safely.



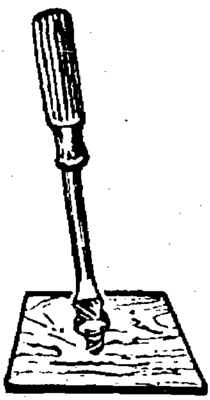
As they use tools for their own projects, children achieve a better appreciation of the role that tools play in everyday life. As they observe the tools more intently, they learn that tools are used because they give us greater force, greater speed, greater convenience, or greater accuracy. The following activities, possible learnings, and safety suggestions may be helpful in teaching about tools.

ACTIVITIES



HAMMERS. Children examine all kinds of hammers and mallets. They use the tools to hammer nails into wood and also to remove nails. They test the magnetized head on the upholsterer's hammer. They compare the weight of a heavy hammer with that of a lighter one.

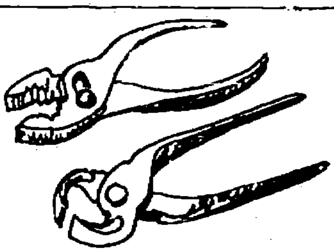
Children examine the handles on the hammers. They check to see how the handles are attached to the heads. They observe the materials in the hammer heads and handles, and relate the materials to the use of this tool.



SCREWDRIVERS. Children may bring in all kinds of screwdrivers and use them to drive screws into a soft piece of wood such as pine. (The teacher may have to drive in nails beforehand to make holes so that it is easier for the children to practice driving in the screws. Soap on the screw threads also makes it easier to drive the screws.)

Children may experiment with joining two pieces of wood which have matching predrilled holes. Use nuts and bolts for fastening. Also, children may practice using a screwdriver to tighten nuts and bolts on their mechanical building sets.

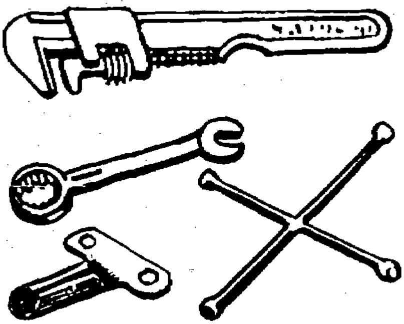
Children conduct a survey to see where wood screws, nuts, and bolts are used in the classroom.



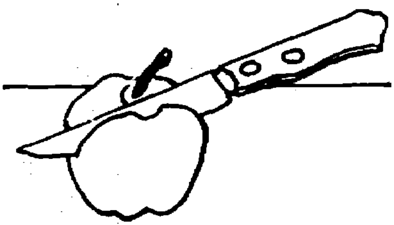
PLIERS. Children may bring an assortment of pliers from home and tell how the pliers are used. In class, they use the pliers to pick up objects, hold things tight, tighten bolts, and snip wire. They become familiar with all kinds of pliers and relate the shape of the tool to its use.

SOME POSSIBLE LEARNINGS	HOW TO USE THE TOOL SAFELY
1. There are many kinds of mallets and hammers. 2. Hammers are shaped for their jobs. 3. Some materials used in hammers are steel, wood, and rubber. 4. Handles are sometimes forced into the head of the hammer and kept there by wedges. 5. A nail is hit hardest when a hammer is held at the end. 6. A nail is pulled out most easily with a claw hammer when the end of the handle is held.	1. Use the proper hammer for the job. 2. Use the hammer that is appropriate for your strength. 3. Do not use a hammer with a loose handle. 4. When nailing, hit gently at first, holding the hammer near the head with one hand, and holding the nail with the other hand until the nail is started. Then take your hand away from the nail, hold the hammer closer to the end, and continue nailing.
1. Screwdrivers are made of many materials; most of them are steel with a wooden or plastic handle. 2. Screwdrivers are shaped differently to perform different jobs. 3. When a screwdriver is turned clockwise, the screw or bolt is driven in; when it is turned counterclockwise, the screw or bolt is loosened. 4. Most screws have points. They may be found holding pencil sharpeners, hinges, and window-shade pulleys to wood. 5. Bolts do not have points. They screw into metal nuts or threaded holes. They may be found on radiators, typewriters, switch plates, etc.	1. Use a screwdriver of the right length, with a head of the correct size to do a job. 2. Do not use a screwdriver as a pick, a chisel, or a crowbar.
1. Pliers are used to do many different jobs: to pick up, grab, twist, cut. 2. When the handles of pliers are closed, the jaws close also. When the handles open, the jaws open. 3. With pliers, things can be held tighter than with fingers alone.	1. Be sure that the jaws of pliers do not slip off an object being worked on, or fingers may be pinched between the handles. 2. Do not hold wire with pliers until it is certain that the wire is not connected to a source of electricity.

ACTIVITIES

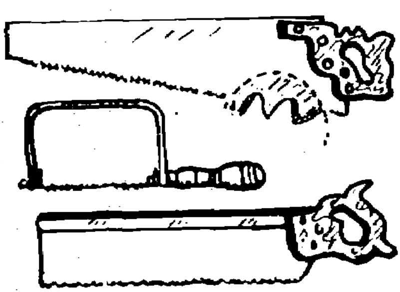


WRENCHES. Children tell where they have seen wrenches used. They learn to identify many kinds of wrenches, and they associate the shape of each wrench with its special use. Have the children use a wrench to tighten a large nut or a bolt holding two pieces of wood together. (See section on screwdrivers.)



KNIVES. Children discuss the various uses of knives and other tools with sharp edges. They list the jobs done with these tools. They discuss how a good workman takes care of his fine tools to protect their edges and to be safe. They see a sharpening stone and wheel and learn how they are used.

The teacher may use a kitchen knife to cut an apple, using both the blunt edge and the sharp edge. The children compare the effort used to do the job in each case.

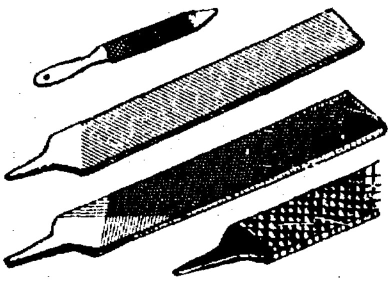


SAWS. Children examine many kinds of handsaws: crosscut saws, ripsaws, hacksaws, and coping saws. They examine the teeth with a magnifying lens and note the sharp cutting edges of the teeth. They also examine the blades and note that they vary in length and in the size and the shape of the teeth.

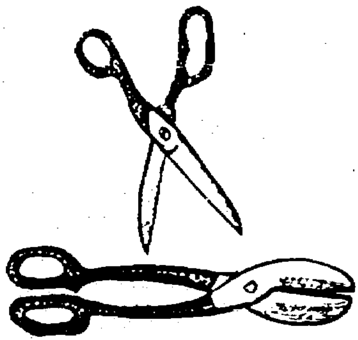
They use a coping saw to cut a thin piece of pine wood, and they learn that the saw cuts best in one direction only. They compare the cutting action of a saw with the cutting action of a knife, and they consider the advantages of the saw. They compare a coping saw to a hacksaw in cutting aluminum or copper tubing.

SOME POSSIBLE LEARNINGS	HOW TO USE THE TOOL SAFELY
1. Wrenches are used to tighten or loosen nuts, bolts, pipes, and some pieces of machinery. 2. Wrenches are made in many sizes. Some wrenches are adjustable. 3. When a wrench with a long handle is used, it is possible to tighten nuts more than when a short-handled wrench is used.	1. Use the proper wrench for the job. 2. Use the correct-sized wrench, or it may slip when you turn it. 3. When using a wrench to tighten a nut on a bolt, do not turn it too hard, or you may strip the threads.
1. Knives have special shapes to do special jobs. 2. Knives should be kept in a safe place. 3. When a knife is sharpened, the rough stone rubs off pieces of metal from the blade to bring it to a sharp edge. 4. When a knife is sharpened on a grinding wheel, sometimes sparks are seen, and the knife gets hot.	1. When you cut with a knife, watch your fingers and cut away from you. 2. Do not keep open knives or other sharp objects in your pockets. 3. Do not use knives or other sharp instruments as toys. 4. Do not use knives as screwdrivers or for prying.
1. A saw has tiny teeth with sharp edges which cut wood or metal when the saw is moved. 2. The tiny teeth work best when the saw cuts the wood in one direction only. 3. Different saws do different jobs. Some saws cut wood; others cut metal. Some saws cut in straight lines; others are better for cutting curves. 4. Sometimes the blade of a saw becomes hot when it is used.	1. Hold work firmly when sawing. 2. Keep fingers out of the way of the saw. 3. Store saws carefully. 4. Use the proper saw for the job.

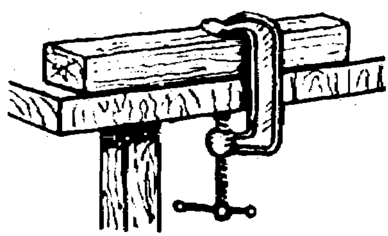
ACTIVITIES



FILES, SANDPAPER. Children examine all kinds of files. They see the teeth on coarse files and use a magnifying glass to examine the teeth on fine files. They feel coarse and fine sandpaper and dip the paper into water to loosen the sand particles. Children bring in nail files and sandpaper and use them to file various materials.



SCISSORS AND SHEARS. Children examine scissors and shears. They observe how the motion of the handles affects the motion of the blades. Ask children for what purposes they use scissors and shears. Experiment by attempting to cut sheet metal with an old pair of scissors and then with shears. Have children relate the shape and the size of the tools to their uses.



CLAMPS AND VISES. Children may bring small clamps, vises, clamp-on lamps, and other devices to school. They also recall where these tools are used at home and in the neighborhood.

A small clamp can be used to hold two rulers securely against each other. Children then try to separate the two rulers and find that it is difficult to do so.

Hold a ruler in a clamp or vise, and ask the children to remove the ruler. Compare the effort needed to remove the ruler when the vise is tight with the effort needed when the vise is loose.

SOME POSSIBLE LEARNINGS	HOW TO USE THE TOOL SAFELY
1. A file has teeth with fine edges which cut into wood and metal when the file is moved across the material. 2. Different files are used for different jobs. 3. A file works best when moved in one direction only. 4. The particles of sand on sandpaper act in the same way as teeth on a file.	1. Use a handle on the tang (pointed end) when using a file. 2. Do not use a file for prying things, since files are brittle and may crack.
1. Scissors and shears are used to cut various materials. 2. Scissors usually have proportionately longer blades and shorter handles than metal shears.	1. Always offer the handles of scissors when they are given to someone. 2. Do not put scissors into your pockets. 3. Do not use scissors for prying, since the blade may snap off. 4. Do not run with scissors in your hands.
1. The jaws of clamps and vises are tightened when a screw on the tool is tightened. 2. A long handle makes it easy to turn the screw in a vise. 3. The tighter the screw is turned in the vise, the tighter the jaws close.	1. A tight clamp can make a mark in soft wood. 2. Do not hammer on the jaws of a vise.

Audio-Visual Materials

The following list of materials has been prepared to implement the teaching of sixth-grade science. All titles listed are approved by the Board of Education. Listings are based on the appraisals of committees of science specialists who preview materials. Utilization of films and other media by individual schools should be based on local previewing and adaption to specific needs.

Asterisks indicate those 16mm films which are available through the BAVI Film Subscription Program. Schools may requisition annual film service or request individual titles. A rental fee is charged for each film loan. Call 596-5912 for rental information.

Other media (filmstrips, transparencies, etc.) may be purchased by schools through either Bureau of Supplies or cash expenditure procedures. In these sections, item numbers (in parentheses) follow those titles which are on the *List of Approved Audio-Visual Materials* and its Supplements. Those titles for which no list number is given should be ordered on a nonlist basis.

Light, Lenses, and the Camera

FILMS

LEARNING ABOUT LIGHT 8 min. EBEC

Deals with fundamental questions in the study of light: Which objects are luminous? When are objects transparent, translucent, or opaque? What is reflection, and what is refraction? Examples from the pupils' daily experiences are amplified with animation.

*LIGHT ALL ABOUT US (C) 11 min. Coronet

Several basic principles of light are demonstrated by means of a story and a few simple experiments.

*LIGHT AND WHAT IT DOES 17 min. EBEC

Demonstrates, through a series of simple problem-solving experiences, how light travels; how it is affected by different materials; what causes reflection and refraction. For grades 5-6.

*PROVE IT WITH A MAGNIFYING GLASS 11 min. Film Assoc.

The film introduces the child to scientific methods by using a science experience with a simple instrument (the magnifying glass) to illustrate the concept that scientific theories must be proved.

*REFRACTION 12 min. McGraw-Hill

Principle of refraction demonstrated in experiments children can do.

FILMSTRIPS

BENDING LIGHT (C) (38756.1) Popular Science

Children learn about the nature of light through simple classroom and home experiments. The phenomenon of refraction is explained as light travels through glass, water, and air.

CAMERA: A MAGIC EYE (C) (38755.13) Popular Science

Functions and applications. How to take good pictures; steps in photographic processing. Interest in photography as a science and hobby stimulated.

HOW LIGHT TRAVELS (C) (37700) Popular Science

How light rays form images in mirrors. Fun with mirrors. How lenses work. Explanation of color. How to make a telescope.

HOW WE SEE AND HEAR (37740) Moody Institute of Science

Structure of the eye and ear. How an object is focused. The eye compared to a camera. How sounds reach our ears.

LIGHT (C) (37925) McGraw-Hill

Story of light; how it travels and why we are able to see certain objects better than others. *Transparent, translucent,* and *opaque* are defined.

LIGHT IN OUR DAILY LIVES (39150.16) Eye Gate

Where light comes from, how it travels, how we see, etc.

LIGHTS, LENSES AND CAMERAS (37028.11) McGraw-Hill

Nature of light and the science of the camera. Topics: how light travels, light refraction, lenses and their function in the camera, etc.

RECORDING FOR THE FUTURE BY PHOTOGRAPHY (37367.17) Eye Gate

How pictures are a means of communication. Use of a camera and of a motion picture camera in recording pictures.

FILM LOOPS (super 8mm, silent)

LIGHT 4 min. Holt, Rinehart & Winston

From the Senses to the Brain

FILMS

*EYES AND SEEING 20 min. EBEC

Gathering reflected light from objects in the environment and bringing this information to the brain as a clear, sharp image is the function of the eye.

HUMAN BRAIN 3¼ min. Harper & Row

LEARNING WITH YOUR EARS 11 min. Coronet

Sounds tell us about the size, power, speed, and distance of objects and sometimes about people's feelings. Various instruments help us learn more from sounds.

LEARNING WITH YOUR EYES 11 min. Coronet

Learning more from seeing, by looking carefully at objects, judging their features and how they change, and fixing them in our minds.

LEARNING WITH YOUR SENSES 11 min. Coronet

Shows how each sense gives us a different kind of information, while all five together can bring us more knowledge and appreciation of the world.

*OUR WONDERFUL BODY: THE HEART AND ITS WORK (C) 11 min. Coronet

A young boy learns about his heart, blood, and blood vessels through the step-by-step construction of a simple circulatory system.

*OUR WONDERFUL BODY: HOW IT GROWS (C) 11 min. Coronet

Shows how different people grow up at different rates, to different sizes; also discusses where the materials that make growth possible come from.

*OUR WONDERFUL BODY: HOW ITS PARTS WORK TOGETHER (C) 11 min. Coronet

Life-size models show how parts of the body operate and how they work together to make running, climbing, seeing, hearing, and thinking possible.

*OUR WONDERFUL BODY: HOW WE BREATHE (C) 11 min. Coronet

A life-size model of a lung and simple demonstrations help a young boy learn about breathing and about ways to keep his lungs healthy.

SOUNDS ARE MADE BY VIBRATING OBJECTS 4 min. Eye Gate

FILMSTRIPS

AIR POLLUTION (36497.71) Popular Science

AIR POLLUTION AND YOU (43017) Current Affairs

The basic problem of air pollution, its principal effects, and some approaches to its control.

Five Senses (set of 5 filmstrips) (37260.00) Jam Handy

The Feel of Your Skin (37260.1)

Tells the story of our sense of touch. Questions and examples stimulate interest. Realistic art and color photography are combined.

Here's Your Ear (37260.11)

To stimulate interest and discussion, there are questions and examples to help the young student to make his own inquiry about the sense of hearing.

How Your Nose Knows (37260.12)

The sense of smell and how we use it to learn about the world around us. Questions and examples stimulate interest and discussion.

Look How Your Eyes See (37260.13)

Realistic art and color photography combined to show how we learn about the world around us by using our sense of sight.

Your Tasting Tongue (37260.14)

Discusses the sense of taste. Questions and examples stimulate interest.

How Do You Know (set of 5 filmstrips and records) (37685) Jam Handy

Describes functions of the senses with explanations and diagrams of the physiology and anatomy of each sense.

Light and Dark (37685.10)

Pain and Pressure (37685.11)

Scent and Smell (37685.12)

Sounds and Silence (37685.13)

Sweet and Sour (37685.14)

Human Senses and Their Limitations (38091.14) Bowmar

Presents the human senses as a source of information about the world. Ends with a discussion of scientific tools designed to extend our limited senses.

Our Senses: Hearing (37367.12) Eye Gate

Explains how sound is produced, discusses the parts of the ear, outlines the purpose of audiometer tests, and lists various ways of protecting our ears.

Our Senses: Seeing (37367.10) Eye Gate

Describes the parts of the eyes and means of protecting our eyesight. Value of sight in the learning process.

Our Senses: Touch, Taste, and Smell (37367.11) Eye Gate

Discusses touching, tasting, and smelling as ways of discovering things. Explains nerve endings under the skin and importance of the tongue.

Understanding Your Body (set of 5 filmstrips) (25279) EBEC

Basic information on the structure, function, and care of the body. Forms a key to the understanding of human biology.

Ears and Hearing (25279.10)

Eyes and Seeing (25279.11)

Nervous System (25279.13)

Skin and Its Functions (25279.15)

Taste, Smell and Touch (25279.16)

World of Sound (33252.000) RMI Film Productions

World of Touch (33254.000) RMI Film Productions

FILM LOOPS (super 8mm, silent)

Exploring the Human Heart 4 min. Harper & Row

Microscope, The 4 min. Holt, Rinehart & Winston

Microscopic World 4 min. Holt, Rinehart & Winston

TRANSPARENCIES

Body, The (8258.10) Instructo

Brain (8258.112)

Central Nervous System (8258.103)

Circulatory System (8258.102)

Digestive System (8258.101)

Ear (8258.107)

Eye (8258.106)

Respiratory System (8258.105)

Skin (8258.110)

Foods and Your Health (set of 12) Ader

Systems of the Human Body (set of 12) Ader

FLAT PICTURES

Air Pollution Life Educational Reprints

How the Computer Gets the Answer Life Educational Reprints

Human Body: Circuits of the Senses Life Educational Reprints

HUMAN BODY: FOOD TO FUEL — Life Educational Reprints

WATER POLLUTION — Life Educational Reprints

RECORDS

YOUR BODY: HOW YOU USE FOOD AND STAY HEALTHY (2 records) — SVE

YOUR BODY: YOUR SENSES AND NERVOUS SYSTEM (2 records) — SVE

Magnets and Electromagnets

FILMS

*ELECTRICITY ALL ABOUT US (EXPLORING SCIENCE) 11 min. — Coronet
Illustrates the characteristics of static electricity, an electrical circuit, and the ways electricity is generated.

*ELECTRICITY FOR BEGINNERS (C) 11 min. — Coronet
Demonstrations in a hardware store show how electricity can produce heat, light and magnetism, and motion in a motor. Emphasizes safety.

*ELECTRICITY: HOW IT IS GENERATED 11 min. — Coronet
Demonstrates basic principles of generation of electricity.

*ELECTRICITY: HOW TO MAKE A CIRCUIT (USING THE DRY CELL) 11 min. — EBF
Three children set up a simple telegraph and learn how to use dry cell batteries safely.

*ELECTROMAGNETS 10 min. — McGraw-Hill
Shows how electromagnets are made and used. Explains the theory of electromagnetism from its use in a simple bar magnet to its use in a completed electromagnet made from simple home materials.

LEARNING ABOUT ELECTRIC CURRENT 8 min. — EBEC
Summary of the generation and use of electricity, including some elementary principles. Wires in a home are traced to a generating station. Simple experiments such as a closed and open circuit and how to make an electromagnet are offered.

MAGNETISM 11 min. — Coronet
Joe has built a telegraph set. In explaining it to Mary, he demonstrates types of permanent magnets, attraction and repulsion, making magnets, fields of force, electromagnets, and the everyday use of magnets.

MAGNETISM AND ELECTRICITY 17 min. McGraw-Hill

Demonstrates the relationship between magnetism and electricity.

FILMSTRIPS

ELECTRIC MAGNETS (36950) Harper & Row

Development of the electric magnet; polarity; uses in industry and daily life.

ELECTRIC POWER (C) (36953) Popular Science

Electricity and electromagnetism as sources of power; voltaic cell, Faraday's discovery and principle; how electricity is generated, transmitted, and used; the stored energy of coal becoming power.

ELECTRICITY IN EVERYDAY LIFE (37365.53) Eye Gate

How electricity is used to make electromagnets; good conductors and insulators; simple circuit; how a switch completes or breaks the electric circuit.

ELECTROMAGNETISM AT WORK (40710.18) Bobbs Merrill

Development of an electromagnet from a coil of wire, use of magnets in the home, instructions for working an electromagnet.

ELECTROMAGNETS AND HOW THEY WORK (39945.1) Jam Handy

How to make an electromagnet using a bolt, wire, and dry cell. How an electromagnet is a temporary magnet; how its strength can be increased.

FINDING OUT ABOUT MAGNETS (36483.41) SVE

Kinds of magnets; laws of polarity; uses of magnets.

MAGNETS (C) (37591.14) Heath

Relationship of magnets to electricity.

MAGNETS WORK FOR US (C) (38033) Popular Science

How magnets and electromagnets are made; their uses.

PRODUCING ELECTRICITY (40710.21) Bobbs Merrill

How electricity can be generated by using magnets or chemicals; what an electric current is; how a generator works; how to make a homemade generator and electric meter; uses of simple generators on bicycles.

FILM LOOPS (super 8mm, silent)

BATTERIES AND BULBS 4 min. Holt, Rinehart & Winston

MAGNETS 4 min. Holt, Rinehart & Winston

MAGNET PATTERNS 4 min. Holt, Rinehart & Winston

The Stars and the Universe

FILMS

*CHARTING THE UNIVERSE WITH OPTICAL AND RADIO TELESCOPES (C) 13 min. — EBEC

Shows that astronomy, like the other sciences, depends on observation, analysis, and insight.

*HOW WE EXPLORE SPACE (C) 17 min. — FAC

Introduction to the instruments astronomers use and the methods by which they obtain information about the objects in space. Telescope, camera, spectroscope, and photocell are demonstrated.

*MILKY WAY 14 min. — UW

Telescopic photography and animation present an expanding picture of the universe by illustrating what stars are and how they are formed.

*RADIO WAVES (PLANET EARTH SERIES) (C) 27 min. — McGraw-Hill

Discusses both man-made and natural radio waves; explains influence of hemisphere on them; describes new science of radio astronomy.

FILMSTRIPS

CONSTELLATIONS (36890.11) — SVE

Major constellations, Orion, Gemini, Pleiades. Reviews pictures of constellations as conceived by ancients; e.g., Orion the Hunter, Cancer the Crab. Summary test at end.

CONSTELLATIONS WE CAN SEE (C) (36740) — Popular Science

How groups of stars (constellations) can be recognized and used to locate other stars in our galaxy at different times of year.

FINDING OUT ABOUT THE UNIVERSE (C) (36460.12) — SVE

Some early theories about the universe and the contributions made by Copernicus, Galileo, Kepler, Newton, and Einstein. Captioned.

HOW WE LEARN ABOUT THE SKY (39480.16) — Jam Handy

Great leaders in astronomy and their contributions. The scientific method is contrasted with the early practices of accepting opinions and superstitions as explanations of these phenomena.

MULTITUDE OF SUNS (39480.1) — Jam Handy

Reduces the immensities of time, space, and size in the stellar world to understandable terms.

STARS AND GALAXIES (36890.12) SVE

Basic facts, e.g., size, number, distance from earth. Explains terms, e.g., light year, parallax, magnitude. Introduces nebulae and galaxies.

STORIES OF THE CONSTELLATIONS (39480.11) Jam Handy

Legends associated with them are used to identify the principal star constellations seen in the northern hemisphere.

WHAT ARE STARS? (37026.12) McGraw-Hill

Compares our sun to the stars. Tells how stars differ by the light they emit, their color, and intensity; solar distances and constellations are discussed.

WORK OF ASTRONOMERS AND SPACE TRAVEL (36890.13) SVE

Types of telescopes (reflector, refractor); use of spectroscope and photometer; explores possibility of space travel and the obstacles to be overcome.

TRANSPARENCIES

ANDROMEDA GALAXY (8255.5) Instructo

BARRED SPIRAL (8256.45) Instructo

CRAB NEBULA (8266.8) Instructo

ORION NEBULA (8297) Instructo

PLEIADES (8305.6) Instructo

RING NEBULA (8309.3) Instructo

SOLAR PROMINENCES (8310.6) Instructo

SPIRAL GALAXY (8311.3) Instructo

STARS AND CONSTELLATIONS—NORTH (8480) Technifax

STARS AND CONSTELLATIONS—SOUTH (8480.1) Technifax

STARS OF THE MILKY WAY (8311.6) Instructo

WHIRLPOOL GALAXY (8350) Instructo

Molecules and Atoms

FILMS

*OUR FRIEND THE ATOM 44 min. Disney

Uses historical approach to lead into atomic structure and applications of atomic energy. Film tells story of the atom and its potential future in the service of peace and progress.

*PARTICLES OF MATTER (C) 20 min. UW

Concerned with essential theories and understanding of mass and energy. Structure, properties, and behavior of atoms are illustrated.

*STATIC ELECTRICITY 10 min. McGraw-Hill

Methods by which static electricity can be created; the molecular theory of electricity; the principle of like and unlike changes, and lightning.

*WHAT ARE THINGS MADE OF? (C) 11 min. Coronet

Film defines and explains composition of matter and its three states: solid, liquid, and gas. Differentiates between an element and a compound and shows that matter can be changed chemically and physically.

FILMSTRIPS

ALL MATTER HAS THREE FORMS (37022.12) McGraw-Hill

Matter exists in one of three forms: solid, liquid, or gas; properties of each of these forms; simple experiments to show how each is affected by heat, cold, and other conditions.

ATOMS AND CHEMISTRY (C) (37591.52) Heath

How atoms combine to form molecules; how molecules form elements and compounds; how compounds form new compounds.

MOLECULES (C) (37591.32) Heath

How molecules can form different substances and how changes in the state of a substance can be brought about by temperature.

PROPERTIES OF MATTER—8 (37002.52) Colonial

Structure of atomic definitions; alpha, beta particles; gamma rays.

FILM LOOPS (super 8mm, silent)

LIQUIDS 4 min. Holt, Rinehart & Winston

The Ocean of Air

FILMS

AIR 8 min. Gateway

Simple uses of air and importance of its properties to life and industry.

*AIR ALL ABOUT US (EXPLORING SCIENCE) 11 min. Coronet

Introduces basic concepts about the physics of air. Watching a feather floating down, David becomes aware of the ocean of air surrounding the earth. In experimenting with a balloon, he learns that air exerts pressure in all directions. This information helps him explain some uses of air.

*AIR ALL AROUND US 11 min. McGraw-Hill

A number of classroom demonstrations illustrate concepts concerning air pressure, contraction and expansion of air, and compressed air.

*AIR AROUND US (C) 14 min. Cenco

Air is a real material, found in soil, water, and living things. It takes up space, has weight, and exerts pressure.

FILMSTRIPS

AIR ABOUT US (35840) Harper & Row

Demonstrations proving existence of air, expansion and contractibility of air, compressibility of air, nature of wind, measurement of air pressure, composition of air.

AIR AND HOW IT BEHAVES (C) (38755.1) Popular Science

Children learn some important physical concepts concerning air through simple experimentation. Importance of air is stressed in weather and in many instruments which are useful to man in his everyday life.

AIR AND ITS PROPERTIES (37022.13) McGraw-Hill

Properties of air: fills space, has weight, exerts pressure, expands when heated, and contracts when cooled.

AIR AND LIFE (39150.11) Eye Gate

Presents concepts involved in study of uses of air.

AIR AND WATER—I (37000.1) Colonial

Properties of air and water.

AIR IS EVERYWHERE (37250.1) Jam Handy

Simple experiments show that air is everywhere.

AIR IS REAL (37250.11) Jam Handy

Simple experiments demonstrate that air is real and occupies space.

AIR PUSHES AGAINST THINGS (37250.13) Jam Handy

Simple experiments to show that air pushes against things.

ALL ABOUT AIR: WHAT AIR DOES (C) (35880.1) Stanley Bowmar

Cartoon strip describing the characteristics of the air making up the atmosphere, how air fills all space and causes work to be done.

INTRODUCING AIR (C) (37829) Bailey

What is wind? Warm and cold air. Air is everywhere.

OUR OCEAN OF AIR (38400) Harper & Row

Depth and stratification of air; instruments and measurements for air pressure; composition of air.

Moving in Air and Space

FILMS

*MAN AND THE MOON (C) 20 min. — Disney

Shows a simulated trip to the moon and return by a rocket ship departing from a previously established space station.

*MAN IN SPACE (C) 27 min. — Disney

Illustrates and discusses rocket development from ancient Chinese weapons to modern missiles. Shows a simulated manned flight into space and man's reaction to weightlessness.

*MARS AND BEYOND 30 min. — Disney

Discusses the possibility of life on Mars and depicts a simulated round trip to Mars.

*ROCKETS: PRINCIPLES AND SAFETY 11 min. — FAC

The physical principles by which rockets work are explained. Stresses that rockets are dangerous and should not be built or fired by amateurs.

*SATELLITES: STEPPING STONE TO OUTER SPACE 15 min. — FAC

Explains what satellites are and why they are important to us. The instruments and their functions aboard the satellite are also shown.

*SCIENCE IN SPACE (PLANET EARTH SERIES) (C) 27 min. — McGraw-Hill

Explains scientific exploration of space and its contents and placing of satellites in orbit. Shows significant discoveries of modern space science, including Van Allen radiation belts.

*SPACE FLIGHT AROUND THE EARTH (C) 11 min. — Churchill

Through this film children experience an actual space flight.

FILMSTRIPS

AIR PUSHES AGAINST THINGS (37250.13) — Jam Handy

Simple experiments to show that air pushes against things.

AIRPLANES AND HOW THEY FLY (39150.14) — Eye Gate

Illustrations of different kinds of aircraft and how they fly.

AIRPLANES, JETS, AND ROCKETS (set of 6 Filmstrips) (35870) — Jam Handy

HOW DO HELICOPTERS FLY? (35870.1)

Parts of a helicopter and uses. Helicopter compared to the airplane; advantages of helicopters; how helicopter goes up and down.

HOW DO JETS FLY? (35870.11)

Principles involved in the operation of jet engines; compared to piston engines; advantages of the jet engines.

HOW IS AN AIRPLANE CONTROLLED? (35870.12)

Parts of the airplane: ailerons, rudder, elevators, and flaps; how these parts operate and are controlled by the pilot.

ROCKET POWER FOR SPACE TRAVEL (35870.13)

Basic principles; construction and performance of rockets as a source of power for space travel; problems of space travel treated.

SAFETY IN FLIGHT (35870.14)

Safety devices on the plane; how the pilot makes use of them. How weather affects plane flying. Uses of weather maps.

WHAT MAKES AN AIRPLANE FLY? (35870.15)

With the aid of simple materials available in the classroom, demonstrations are presented that show what makes an airplane rise and fly.

CONTROLLING AIRPLANES (39130.12) McGraw-Hill

Effect of ailerons, rudder, and elevators on the motion of a plane.

FLYING JETS AND ROCKETS (39130.11) McGraw-Hill

Principle of gas pressure, action and reaction as applied to jet propulsion in planes and rockets.

LIFE ABOVE THE ATMOSPHERE (C) (37591.74) Heath

Physical principles involved in the hazards of space travel.

OFF WE GO (37365.11) Eye Gate

Shows progress in the area of transportation. Walking, beasts of burden, rafts, boats, carts, chariots, wagons, and automobiles are shown. Development of transportation in this country—the covered wagon, stagecoach, pony express, steamboat, locomotive, automobiles, planes, helicopters, rockets—is outlined.

OVERCOMING GRAVITY (39130.14) McGraw-Hill

Properties of air and how it can be used to produce lifting of balloon and lift on airplane wing.

PROJECT APOLLO (C) (38756.17) Popular Science

Step-by-step events in the project Apollo moon shot. Role of the command, service, and lunar excursion modules in the lunar venture.

SATELLITES (C) (37040.21) Popular Science

Clear and simple explanation of how a satellite gets into space and remains in orbit. Satellites in communication, weather, navigation, and space travel help mankind in the space age.

SCIENCE AT THE AIRPORT (37028.12) McGraw-Hill

Operations required to put a plane into flight—from the hangar until plane is airborne. Interdependence of parts; smoothly functioning, science-oriented airport team.

Space Flight: Orbiting the Earth (C) (37591.62) Heath

How satellites orbit. How spaceships escape the earth's pull. The principles of gravity and inertia.

Space Flight: Rocket Propulsion (C) (37591.63) Heath

Principle of action/reaction.

Space Flight: Weight and Weightlessness (C) (37591.64) Heath

Why objects become weightless when the rocket engine burns out; principles of gravity and inertia.

FILM LOOPS (super 8mm, silent)

Pendulums 4 min. Holt, Rinehart & Winston

Springs 4 min. Holt, Rinehart & Winston

TRANSPARENCIES

Parts of an Airplane (C) (8299) Instructo

Bibliography

The publications for children listed in this Bibliography have been selected to:

provide good reading in science
convey the meaning and spirit of elementary science
provide science content related to the course of study
provide enriched material for pupils with special science interests
suggest valuable classroom procedures, experiments, and projects.

Most of the books are on either of the following lists of the Board of Education of the City of New York: *Library Books for Elementary and Junior High Schools;* or *Textbooks: Elementary and Junior High Schools.* For approaches to the use of these and other books, see Science and the Reading Program on pages 13-14.

Following the list of children's books is a list of professional books on the teaching of science in the elementary school.

FOR PUPILS

Light, Lenses, and the Camera

BEELER, NELSON F., AND BRANLEY, FRANKLYN M. *Experiments with Light.* New York: Crowell, 1958.

Clearly and accurately presents experiments for finding out about light.

FREEMAN, MAE AND IRA. *Fun and Experiments with Light.* New York: Random House, 1963.

Suggests using materials found in the home in simple experiments illustrating principles of light.

HARRISON, GEORGE R. *The First Book of Light.* New York: Franklin Watts, 1962.

Answers questions about light simply. Suggests a variety of experiments using home equipment.

HEALY, FREDERICK. *Light and Color.* New York: Golden, 1966.

Tells where light comes from, how it works, what it does. Includes experiments a child can do.

JUPO, FRANK. *The Adventure of Light*. Englewood Cliffs, N.J.: Prentice-Hall, 1958.

Tells in word and picture how man brought light to his surroundings. Explores recent developments and things to come. Has high interest level, low reading level.

KOHN, BERNICE. *Light*. New York: Coward-McCann, 1965.

Presents a simple introduction to light with suggestions for easy experiments that can be tried at home.

LIEBERO, OWEN S. *Wonders of Heat and Light*. New York: Dodd, Mead, 1966.

Discusses light as a form of energy and tells how light is put to work for man.

NEAL, CHARLES D. *Exploring Light and Color*. Chicago: Childrens Press, 1964.

Has attractive, clear print; good illustrations; diagrams easy to interpret. Explores topics such as light, color, mirrors, and lenses.

RUCHLIS, HY. *The Wonder of Light*. New York: Harper, 1960.

Using photographs and diagrams, explains how and why we see. Explores reflection and refraction and the instruments that show their application.

SOOTIN, HARRY. *Light Experiments*. New York: Norton, 1963.

Accompanies each experiment by easily understood explanations of the principles and scientific history involved. Suggests inexpensive and easily obtained materials.

ZIM, HERBERT S., AND BURNETT, R. WILL. *Photography*. New York: Simon and Schuster, 1956.

Explains how the amateur can take better pictures. Covers all basic principles of the art and science of making better pictures.

From the Senses to the Brain

ADLER, IRVINO AND RUTH. *Taste, Touch and Smell*. New York: John Day, 1966.

Describes how these senses work through the nervous system and tells what purpose each of them serves.

ALIKI. *My Five Senses*. New York: Thomas Y. Crowell, 1962.

Develops, with simple words and attractive pictures, an understanding of the senses and what is learned about the world through them. Has high interest level and low reading level.

BENDICK, JEANNE. *The Human Senses*. New York: Franklin Watts, 1968.

Demonstrates how the five senses work by posing and answering pertinent questions.

BLOCKMAN, LAWRENCE. *Understanding Your Body*. New York: Crowell-Collier, 1968.

Presents the basic anatomical systems of the body. Is easy to read.

CARLSON, CARL WALTER AND BERNICE WELLS. *Water Fit to Use*. New York: John Day, 1966.

Explains why some water is good for drinking while some must be treated if it is to be used. Examines the necessary but expensive job of reclaiming polluted water. Is a good teacher reference.

ELGIN, KATHLEEN. *Read About the Brain*. New York: Franklin Watts, 1967.

Describes some of the major parts of the brain and how they work together to make us intelligent.

———. *Read About the Ear*. New York: Franklin Watts, 1967.

Offers a simple introduction to the structure and functioning of the ear.

———. *Read About the Eye*. New York: Franklin Watts, 1967.

Offers a simple introduction to the structure and functioning of the eye.

———. *The Human Body: The Respiratory System*. New York: Franklin Watts, 1970.

Offers a simple introduction to the structure and functioning of the human respiratory system.

KLAGSBURN, FRANCINE, AND SAMUEL. M.D. *Your Health: Nutrition*. New York: Franklin Watts, 1970.

Introduces nutrition. Discusses nutrients and their uses, balanced diets, and caloric requirements of children of different ages.

PERRY, JOHN. *Our Wonderful Eyes*. New York: McGraw-Hill, 1955.

Offers simple experiments to show how the eyes work.

RAVIELLI, ANTHONY. *Wonders of the Human Body*. New York: Viking, 1954.

Shows the interdependence of all parts of the body.

SCHNEIDER, HERMAN AND NINA. *How Your Body Works*. New York: William R. Scott, 1949.

Presents simple physiology, with some activities and experiments. Emphasizes the viewpoint that a healthy body should be kept healthy.

Magnets and Electromagnets

ADLER, IRVING. *Electricity in Your Life*. New York: John Day, 1965.

Presents basic facts about electricity, its nature, history, and uses in the modern world. Includes activities.

FREEMAN, IRA M. *All About Electricity*. New York: Random House, 1957.

Explains, with very clear line drawings, what electricity is and how it works in many devices.

HARVEY, TAD. *The Quest of Michael Faraday*. New York: Doubleday, 1963.

Explains Faraday's experiments in electromagnetism dramatically.

ROSENFELD, SAM. *The Magic of Electricity*. New York: Lothrop, Lee and Shepard, 1963.

Offers clear diagrams for the student to carry out experiments with electricity.

SHEPHERD, WALTER. *Electricity*. New York: Golden, 1966.

Tells how scientists of the past learned about electricity, so that students understand where electricity comes from, how it is made, and how it works. Gives instructions on how to make a simple telegraph and an electric motor.

SOOTIN, HARRY. *Experiments with Electric Currents*. New York: Norton, 1969.

Outlines many experiments in electricity so that children may follow them and learn more about electric current.

WEISS, HARVEY. *Motors and Engines and How They Work*. New York: Thomas Y. Crowell, 1969.

Includes a section on how to make an electric motor from scrap materials.

The Stars and the Universe

ADLER, IRVING. *The Stars: Steppingstones into Space*. New York: John Day, 1956.

Clearly explains evidence and reasoning scientists have used to reach conclusions about the stars.

BRANLEY, FRANKLYN M. *A Book of Stars for You*. New York: Thomas Y. Crowell, 1967.

Deals with the birth, composition, size, temperature, source of energy, density, motion, and relative position of stars in a clear and easily understood manner.

———. *A Book of the Milky Way Galaxy for You*. New York: Crowell, 1965.

Explains the size and shape of the Milky Way and how such discoveries were made. Discussion of the composition of the galaxy and its relationship to other galaxies.

———. *The Big Dipper*. New York: Thomas Y. Crowell, 1962.

Gives directions for locating the Big Dipper. Discusses what we know about this famous group of stars and some folklore and legend connected with the Big Dipper. Is easy to read.

———. *The Christmas Sky*. New York: Thomas Y. Crowell, 1966.

Has its origin in the traditional Christmas Show at the Hayden Planetarium. Tells the story of the Wise Men's journey and discusses the theories astronomers have advanced about the guiding star.

ENGELBREKTSON, SUNE, AND GREENLEAF, PETER. *Let's Explore Outer Space*. New York: Sentinel, 1969.

Includes many interesting experiments in astronomy which help students understand the techniques scientists use in exploring outer space.

FREEMAN, MAE AND IRA. *Fun with Astronomy*. New York: Random House, 1953.

Discusses many interesting phenomena which can be seen with the naked eye in the night sky: star clusters, nebulas, and double stars.

FROMAN, ROBERT. *Faster and Faster*. New York: Viking, 1965.

Discusses speed. Offers a fascinating account of ascending scale of speeds in the universe from slow movement of glaciers to high speed of light waves.

GALLANT, ROY. *Exploring the Universe*. New York: Doubleday, 1968.

Offers an understanding of the universe traced from ancient beliefs to the present.

JOSEPH, JOSEPH MARON, AND LIPPINCOTT, SARAH LEE. *Point to the Stars*. New York: McGraw-Hill, 1967.

Describes the simple "face-and-point" method used to locate stars, constellations, and planets. Begins with heavenly bodies which can be seen with the naked eye; then moves to objects which are visible through binoculars and those which can be seen only with a telescope. Also includes folklore and mythology associated with the stars.

KING, HENRY C. *Our World in Space: An Easy Guide to the Universe*. Philadelphia: Macrae Smith, 1964.

Briefly summarizes man's knowledge and observations of space, and its organization into a universe. Is addressed to both advanced elementary school pupils and adults.

KNIGHT, DAVID C. *Comets*. New York: Franklin Watts, 1968.

Includes information on the origin and evolution of comets, ancient beliefs about comets, and comments on future research.

NEAL, CHARLES D. *Exploring Light and Color*. Chicago: Childrens Press, 1964.

Offers directions for constructing Galilean telescope, astronomical telescope, and prism spectroscope.

PICKERING, JAMES S. *Famous Astronomers*. New York: Dodd, Mead, 1968.

Presents the story of astronomy through the lives and works of Aristotle, Ptolemy, Copernicus, Kepler, Galileo, Newton, and Herschel.

POLGREEN, JOHN AND CATHLEEN. *The Stars Tonight*. New York: Harper and Row, 1967.

Offers an excellent guide to the night sky, star charts, viewing guides, and background information grouped according to months of the year.

RONAN, COLIN A. *The Stars.* New York: McGraw-Hill, 1966.

Moves from familiar sights of the stars to explain the phenomena visible only through a telescope or rarely seen: nova. supernova, and other galaxies.

SCHNEIDER, HERMAN AND NINA. *You Among the Stars.* New York: William R. Scott, 1951.

Has magnificent illustrations and poetic text which make it an excellent first book of astronomy, simplifying vast concepts and giving the child a feeling of his place in the universe.

WOLFE, LOUIS. *Let's Go to a Planetarium.* New York: Putnam, 1958.

Recounts experiences at a planetarium. Is a good introduction to a trip to the planetarium.

Molecules and Atoms

BEELER, NELSON F., AND BRANLEY, FRANKLYN M. *Experiments in Chemistry.* New York: Thomas Y. Crowell, 1952.

Deals with chemistry in everyday life; gives simple experiments with salt, soap, sugar, flour, milk, starch, and other materials available in the kitchen.

BISHOP, GEORGE. *Atoms at Work.* New York: Harcourt, Brace, 1951.

Presents information for interested children and for teachers who want a simple explanation of atoms and molecules.

BRONOWSKI, J., AND SELSAM, MILLICENT E. *Biography of an Atom.* New York: Harper and Row, 1965.

Discusses the carbon atom in simple language. Has very clear illustrations.

COOPER, ELIZABETH K. *Discovering Chemistry.* New York: Harcourt, Brace & World, 1959.

Presents simple experiments; discusses their meaning and application.

FERMI, LAURA. *The Story of Atomic Energy.* New York: Random House, 1961.

Is written by the widow of Enrico Fermi, the atomic physicist. Gives a brief survey of the contributions of scientists to an understanding of the structure of the atom, and lists the ways in which atomic energy can be released.

FREEMAN, IRA M. *All About the Atom.* New York: Random House, 1955.

Helps children understand the structure and energy of an atom.

FREEMAN, MAE AND IRA. *The Story of Chemistry.* New York: Random House, 1962.

Presents a simple account of the history of chemistry.

———. *The Story of the Atom.* New York: Random House, 1960.

Offers a simplified history of the atom.

GALLANT, ROY A. *The ABC's of Chemistry.* New York: Doubleday, 1963.
Is a large book organized alphabetically to introduce young readers to chemical change.

GOLDIN, AUGUSTA. *Salt.* New York: Thomas Y. Crowell, 1965.
Is easy to read; gives importance, characteristics, and origin of salt.

NEWCOMB, ELLSWORTH, AND KENNY, HUGH. *Alchemy to Atoms.* New York: Putnam, 1961.
Presents the work of chemists of old and discusses new areas to be explored by modern scientists; excites the especially interested child.

SCHNEIDER, HERMAN AND NINA. *How Big Is Big? From Stars to Atoms.* New York: Scott, 1950.
Helps in understanding the size of atoms and molecules in relation to the child and the universe.

SCHWARTZ, JULIUS. *Its Fun to Know Why: Experiments with Things Around Us.* New York: McGraw-Hill, 1952.
Offers simple experiments that show how man obtains and uses salt, iron, coal, glass, paper, bread, wool, cement, rubber, and soap.

———. *Through the Magnifying Glass: Little Things That Make a Big Difference.* New York: McGraw-Hill, 1954.
Discusses exploring crystals, atoms, and other wonders with a simple magnifier.

The Ocean of Air

ADLER, IRVING. *Weather in Your Life.* New York: John Day, 1959.
Explores ways of studying, forecasting, and changing the weather. For interested children and teachers.

ANTOINE, TEX. *Wonders of the Weather.* New York: Dodd, Mead, 1962.
Shows by diagrams how things we already know can be applied to weather.

FENTON, CARROLL L. AND MILDRED A. *Our Changing Weather.* New York: Doubleday, 1954.
Presents a factual, straightforward description of weather phenomena, illustrated with diagrams and photographs.

FORRESTER, FRANK. *1001 Questions Answered About the Weather.* New York: Dodd, Mead, 1957.
Asks and answers more than 1200 questions about every important aspect of weather; gives accurate and concise information.

GALLANT, ROY A. *Exploring the Weather.* Garden City: Garden City Books, 1957.
Has very good illustrations to help children explore the weather. Contains a fine chapter on our ocean of air.

KNIGHT, DAVID C. *Let's Find Out About Weather.* London: Watts, 1967.
Contains basic information.

MILGROM, HARRY. *Understanding Weather.* New York: Crowell-Collier, 1970.
Offers an introduction to basic weather facts, theories, and recent scientific developments, including weather satellites; is enlivened with illustrations and suggestions for firsthand experiments and experiences. Information presented on easy-to-read charts.

MILGROM, HARRY, AND RUCHLIS, HY. *Science Book of Air Experiments.* New York: Science Materials Center, 1961.
Presents experiments with simple materials to develop fundamental concepts about weather.

NEWELL, HOMER E. *Window in the Sky.* New York: McGraw-Hill, 1959.
Gives the story of our atmosphere; for upper grade students.

PILKINGTON, ROGER. *The Ways of the Air.* New York: Criterion, 1962.
Gives the information basic to the understanding of air and weather. A resource book for the teacher and the interested student.

PRESTON, EDNA MITCHELL. *Air.* Chicago: Follett, 1965.
Has high interest level; easy reading level. Helps the student to understand the ocean of air that surrounds the earth.

SCHNEIDER, HERMAN. *Everyday Weather and How It Works.* New York: McGraw-Hill, 1961.
Reduces complexities of weather to three factors: heat, air, and water. Presents simple experiments.

SPAR, JEROME. *The Way of the Weather.* Mankato, Minn.: Creative Educational Society, 1967.
Offers full-page photographs with facing one-page text to explain many aspects of weather.

STAMBLER, IRWIN. *Breath of Life: The Story of Our Atmosphere.* New York: Putnam, 1963.
Points out how man depends upon his atmosphere, how much he has learned about it, and how he investigates it; is written for interested students and teachers.

TANNEHILL, IVAN R. *All About the Weather.* New York: Random House, 1953.
Explains how to observe weather and how forecasts are made.

WOLFE, LOUIS. *Probing the Atmosphere: The Story of Meteorology.* New York: Putnam, 1961.
Discusses the history of weather science and the men who developed it.

WYLER, ROSE. *The First Book of Weather.* New York: Franklin Watts, 1956.
Explains what makes weather; gives simple experiments and directions for making weather instruments and reading weather maps.

ZIM, HERBERT S.; LEHR, PAUL E; AND BURNETT, R. WILL. *Weather*. New York: Simon and Schuster, 1957.

Offers information for the pupil who has an unusual interest in weather.

Moving in Air and Space

BENDICK, JEANNE. The *First Book of Space Travel*. New York: Franklin Watts, 1963.

Helps the child understand the what, where, and how of space travel.

COOKE, DAVID C. *Behind the Scenes at an Airport*. New York: Dodd, Mead, 1958.

Discusses the work done at a large metropolitan airport, including behind the scene activities.

COOMBS, CHARLES I. *Airmen and What They Do*. New York: Franklin Watts, 1958.

Presents information on aviation careers and opportunities, civilian and military.

———. *Survival in the Sky*. New York: William Morrow, 1956.

Instructs the student interested in learning about the dangers of flying airplanes and the aids to overcoming these dangers.

CORBETT, SCOTT. *What Makes a Plane Fly?* Boston: Little, Brown, 1967.

Uses numerous examples and clear, concise language to explain how an airplane rises and stays aloft.

CROSBY, ALEXANDER. *The World of Rockets*. New York: Random House, 1965.

Tells how rockets work; presents the problems and dangers astronauts face in space and what we hope to learn by exploring the moon and planets.

DELEAR, FRANK J. *The New World of Helicopters*. New York: Dodd, Mead, 1967.

Presents the exciting story of helicopters, their present and future operations.

GOTTLIEB, WILLIAM P. *Aircraft and How They Work*. Garden City: Garden City Books, 1960.

Includes easy demonstrations explaining principles of flight, illustrated with color photographs and drawings.

———. *Space Flight and How It Works*. Garden City: Doubleday, 1963.

Explains, with simple experiments, jet propulsion, orbits of satellites, escape from the earth, weightlessness, and other aspects of space flight.

HALACY, DANIEL S. JR. *Father of Supersonic Flight: Theodor von Karman*. New York: Messner, 1965.

Is an interesting biography about the development of supersonic flight.

HENDRICKSON, WALTER B. JR. *Winging into Space*. Indianapolis, Ind.: Bobbs-Merrill, 1965.

Discusses the area of experimental research concerning the development of new concepts in airplane design.

KINNEY, WILLIAM A. *Medical Science and Space Travel*. New York: Franklin Watts, 1959.

Explains how medical science meets the challange of putting men into space.

LOOMIS, ROBERT D. *All About Aviation*. New York: Random House, 1964.

Discusses the historical development of aviation from the work of the Wright Brothers to the supersonic transports; includes what it is like to pilot a small plane; discusses the scientific principles involved in flying and the instruments that help to make flying safe.

MILGROM, HARRY. *Explorations in Science*. New York: Dutton, 1961.

Describes twenty basic experiments that children can perform with simple materials.

———. *First Experiments with Gravity*. New York, Dutton, 1966.

Presents twenty basic experiments on gravity, using simple materials, with important implications for air and space travel.

———. *Further Explorations in Science*. New York: Dutton, 1963.

Explains fundamental experiments that children can perform in school and at home.

PAUST, GIL. *How a Jet Flies*. New York: Sterling, 1962.

Offers historical development of the jet plane; takes the reader on an imaginary flight detailing every operation from takeoff to landing.

RESS, ETTA SCHNEIDER. *Signals to Satellites in Today's World*. Mankato, Minn.: Creative Educational Society, 1966.

Presents a picture-text review of man's ways of communicating, with special emphasis on telecommunications and achievements by scientists from many lands.

SCHNEIDER, LEO, AND AMES, MAURICE U. *Wings in Your Future*. New York: Harcourt, Brace, 1955.

Presents the principles of flight with simple experiments.

STEVER, GUYFORD H.; HAGGERTY, JAMES J.; and the Editors of *Life*. *Flight*. New York: Time, Inc., 1965.

Discusses the operation and control of the modern jet plane. Includes color photographs and schematic drawings showing principles of flight.

VICTOR, EDWARD. *Planes and Rockets*. Chicago: Follett, 1965.

Explains, in simple language, what makes planes and rockets operate.

WELLS, ROBERT. *Navigation in the Jet Age*. New York: Dodd, Mead, 1961.

Discusses navigation science, that is, the operation of equipment for guiding planes, ships, and submarines.

FOR TEACHERS

BLOUGH, GLENN O., AND SCHWARTZ, JULIUS. *Elementary School Science and How to Teach It.* New York: Holt, Rinehart & Winston, 1969.

Combines a survey of science content with methods of teaching science in the elementary school.

CARRIN, ARTHUR, AND SUND, ROBERT B. *Teaching Science Through Discovery.* Columbus, Ohio: Merrill, 1966.

Emphasizes planning and evaluation for a series of representative lessons.

CRAIG, GERALD S. *Science for the Elementary School Teacher.* Boston: Ginn, 1966.

Provides the teacher with background information in science and with methods of teaching it.

DUNFEE, MAXINE. *Elementary School Science: A Guide to Current Research.* Washington, D.C.: Association for Supervision and Curriculum Development, NEA, 1967.

Offers a survey of recent research developments and thinking in elementary science.

GEGA, PETER C. *Science in Elementary Education.* New York: John Wiley, 1970. Suggests methods of science teaching and the application of these methods in suggested units.

HENNESSY, DAVID E. *Elementary Teacher's Classroom Science Demonstrations and Activities.* Englewood Cliffs, N.J.: Prentice-Hall, 1964.

Offers materials and procedures in elementary science.

HONE, ELIZABETH B., and others. *A Sourcebook for Elementary Science.* New York: Harcourt, Brace, 1962.

Suggests techniques and procedures for teaching science.

HUBLER, CLARK. *Working with Children in Science.* Boston: Houghton Mifflin, 1957.

Discusses problems of teaching science in the elementary school.

HURD, PAUL DEHART, AND GALLAGHER, JAMES JOSEPH. *New Directions in Elementary Science Teaching.* Belmont, California: Wadsworth, 1968.

Presents new programs in elementary science and their theoretical foundations.

KAMBLY, PAUL E., AND SUTTLE, JOHN E. *Teaching Elementary School Science—Methods and Resources.* New York: Ronald, 1963.

Outlines orientation to the subject with specific suggestions for developing teaching units.

KARPLUS, ROBERT, AND THIER, HERBERT D. *A New Look at Elementary School Science.* Chicago, Ill.: Rand McNally, 1967.

Describes goals, content, and specific teacher roles of one of the national projects, namely, the Science Curriculum Improvement Study (SCIS).

KAVALER, LUCY. *Dangerous Air.* New York: John Day, 1967.

Presents the true story of air pollution: the pollutants, sources and effects; gives suggestions for reducing air pollution.

KUSLAN, LOUIS I., AND STONE, A. HARRIS. *Teaching Children Science: An Inquiry Approach.* Belmont, Calif.: Wadsworth, 1968.

Analyzes research that supports use of modern teaching methods.

LEWIS, JUNE E., AND POTTER, IRENE. *The Teaching of Science in the Elementary School.* Englewood Cliffs, N.J.: Prentice-Hall, 1961.

Gives teaching suggestions and subject matter.

NAVARRA, JOHN G., AND ZAFFARONI, JOSEPH. *Science Today for the Elementary School Teacher.* New York: Harper, 1960.

Gives teaching suggestions and subject matter.

PILTZ, ALBERT, AND SUND, ROBERT. *Creative Teaching of Science in the Elementary School.* Boston: Allyn and Bacon, 1968.

Discusses how to develop children's creative potential in science.

RENNER, JOHN W., AND RAGAN, WILLIAM B. *Teaching Science in the Elementary School.* New York: Harper, 1968.

Discusses the contributions of science education to the objectives of the elementary school.

TANNENBAUM, HAROLD E.; STILLMAN, NATHAN; AND PILTZ, ALBERT. *Science Education for Elementary School Teachers.* Boston: Allyn and Bacon, 1965.

Suggests goals, methods, principles of child development in relation to elementary school science.

TRIEGER, SEYMOUR. *Atoms and Molecules.* Darien, Conn.: Teachers Publishing, 1964.

Is one of a series of booklets for teachers; offers excellent suggestions for individual experimentation.

VESSEL, M.F. *Elementary School Science Teaching.* New York: Center for Applied Research in Education, 1963.

Traces the history of elementary school science; includes curriculum organization and classroom procedures.

VICTOR, EDWARD. *Science for the Elementary School.* New York: Macmillan, 1965.

Offers teaching methods and outlines of content.

VICTOR, EDWARD, AND LERNER, MARJORIE S. *Readings in Science Education for the Elementary School.* New York: Macmillan, 1967.

Presents readings on current thinking, practices, and innovations in elementary science education.