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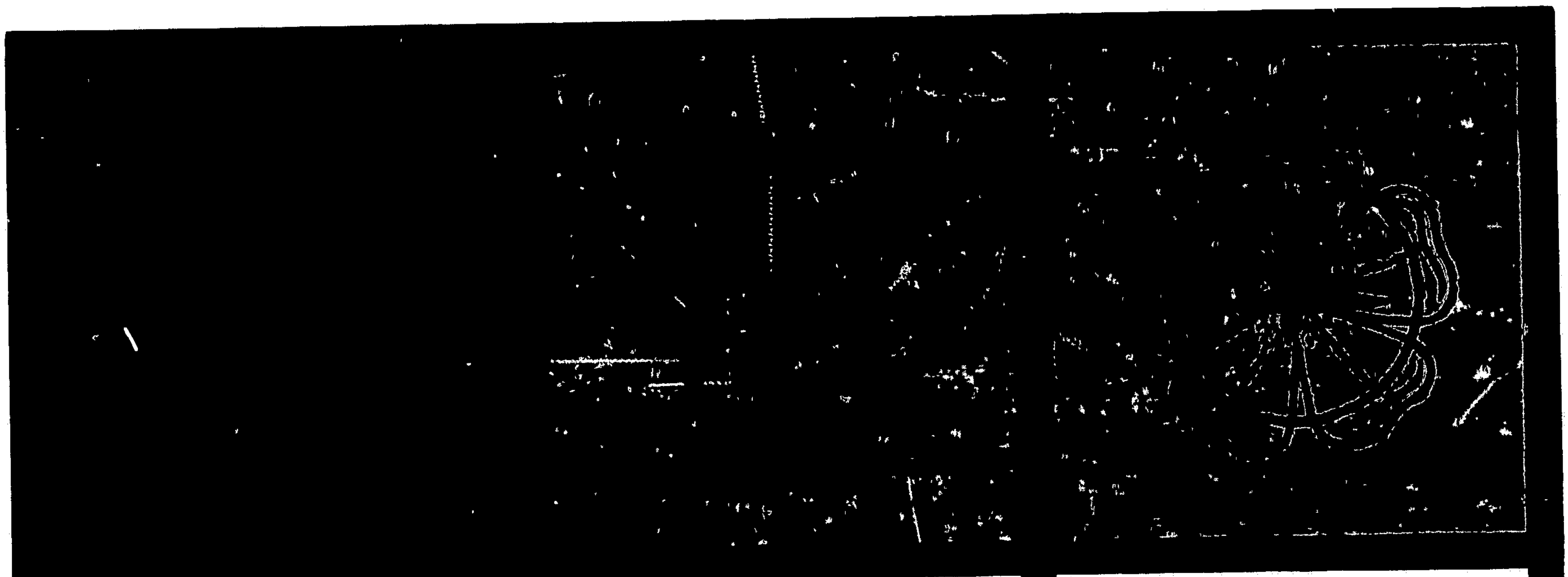
This booklet was written for students as a source of ideas for research type science projects. Part One shows how three high school students developed individual projects as a result of asking questions about the same natural phenomena. Part Two contains project suggestions and sample questions designed to stimulate student thinking along research project lines. "Only those suggestions and questions are included that will yield some degree of success." Part Three is a guide to references. The authors have limited the entries to those of known value. Subject matter categories for which project ideas are presented include biology, chemistry, physics, and general science. (BC)



Ideas for Science Projects

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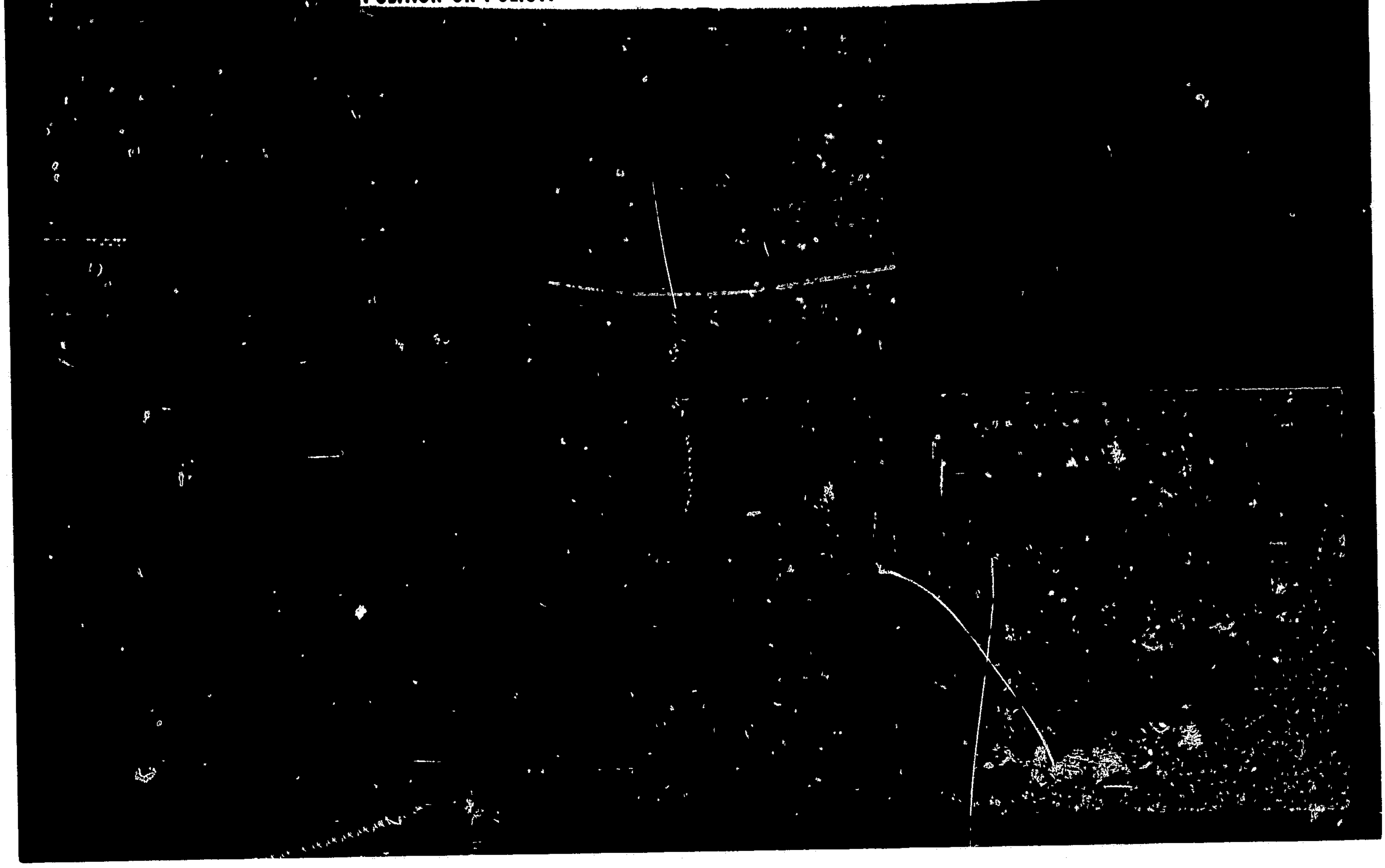

Ideas for SCIENCE PROJECTS

NATIONAL SCIENCE TEACHERS ASSOCIATION
A department of the National Education Association
1201 Sixteenth Street, N. W., Washington 6, D. C.

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Washington 6, D. C.

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FOREWORD

The youth activities program of the National Science Teachers Association is founded on the conviction that in the education of science-oriented students, opportunities should be provided for them to have experiences similar to those of practicing scientists. Accordingly NSTA, with considerable help and support from many individuals, groups, and organizations, has undertaken or assisted in numerous programs aimed at this target. Outstanding programs include the following:

Future Scientists of America Awards
Future Scientists of America Clubs
Youth Science Seminars and Congresses
International Youth Science Fortnights (London, England) and European Science Study Tours
Vistas of Science Books

More often than not, the key to a student's "getting started" is an intriguing laboratory or field experience. This is normal and as it should be since such activity is the very heart and core of the total scientific endeavor. To help secondary school science teachers working with students who want to do a science project is the main purpose of this book.

It represents a serious effort to suggest kinds of projects suitable for students to undertake and which represent "tactics and strategy" (scientific methods) actually employed by practicing scientists. In other words, the advice and help offered here stress the investigative or research-type of project.

But this book is not based on mere "armchair quarterbacking"; and it is far more than a list of project titles. Practicing science teachers have contributed from their rich experiences. Some of the ideas are based on abstracts of projects done by recent students some of which have won awards or honorable mention in the annual programs of FSA Awards. The test of *Ideas for Science Projects* will come with actual use by teachers and students. We are confident your reports will be favorable.

To all who have contributed, we extend the thanks and appreciation of the Association officers and the Board of Directors. In addition to acknowledging the work of the current authors, we include the contribution of John H. Woodburn. Some of his projects taken from earlier Association publications have been merged into this book. Staff members who gave special assistance also in this total effort were Glenn E. Warneking, John W. Renner, and Dorothy T. Tryon.

ROBERT H. CARLETON, *Executive Secretary*
National Science Teachers Association

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INTRODUCTION

Ideas for Science Projects is a book designed for students and teachers in which numerous questions and problems have been introduced. The authors hope that the material developed will assist high school students in experiencing the satisfaction and enjoyment of solving actual problems in science. *Ideas for Science Projects* is written for students as a source of ideas for research-type science projects. All science projects have value and undoubtedly much may be learned by assembling an oscilloscope kit, constructing a model of a steel mill, or doing experiments to verify a scientific principle. The truly investigative project, however, offers the students a more profound experience embodying the nature of science and the spirit of inquiry.

Ideas for Science Projects is *not* a book of recipes or directions which will guarantee a successful science project. Science has no hard-and-fast rules for methods of investigation. "Methods" are part of the creative process of science, and each investigator must formulate his own modes of inquiry. Part One shows how three high school students developed individual projects which came from asking questions about the same natural phenomenon, the rise of sap in plants.

If you are not sure of what to expect as you do a science project, Part One will give you a review of the difficulties and satisfactions that three students encountered; namely, Colleen, Scott, and Herb. Your project will undoubtedly provide a different set of experiences. When you do conclude a research-type science project, however, your personal satisfaction will be unique. No one will have done exactly the same thing.

Part Two contains many project suggestions and sample questions for another kind of investigation that may be undertaken. As you read about each phenomenon described, other questions inevitably will arise. Only those questions and project suggestions have been included which will yield some degree of success. Here, then, is a source of practical project problems.

Part Three is a guide to references which will help you in conducting a science project. We have limited the entries to those which are known to be of value. You will certainly find other resources of your own.

Not all of the ideas presented here are original, but it would be impossible to credit each source properly. Some have come from students, some from science teachers, others from forgotten reading references. We acknowledge with appreciation the specific contributions and aid from the materials assembled by the Future Scientists of America of NSTA; Gerald Acker, *Executive Secretary* of the Ohio Junior Academy of Science, Columbus, Ohio; and the students and secretarial staff of the University School, Columbus, Ohio.

The authors and the Association eagerly solicit criticism, comments, and suggestions for revisions and additions.

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PART ONE
Project Development

I. Sap-Rise Phenomenon

When plants evolved from sea to land, one problem that needed to be solved was the transportation of water from the soil to the aerial portions of the plants. Structurally, we see that a tube-like tissue called *xylem* was developed which conducts the sap in an upward direction. Yet, many questions on how the water rises from roots to higher organs remain unanswered.

If man had been the architect of plants, a mechanical pump might have been the means by which water is transferred from the ground to plants. No such device, however, can be observed in an oak tree or in a petunia. If there is something in plants that acts like a pump, it must be made of the plant cells themselves.

The natural pump in plants accomplishes some amazing results. A palm tree may be one hundred feet high. During an average day this tree may evaporate as much as 150 gallons of water from the leaves clustered near its top. Each day the pump in the tree lifts its water over one-half ton, to a height equal to a seven-story building, expanding energy equivalent to carrying five gallons of water (45 lb) up seven flights of stairs thirty times each day.

The Douglas Fir, the Coast Redwood, and other trees grow taller than 300 feet. Though these trees probably do not use as much water as the palm, their internal pumps must force water three times as high. One redwood is known to be taller than a twenty-five-story building.

Can You Answer These?

Is the height to which a tree can grow limited?

Could plant pumps force water to an indefinite height?

How are plants, especially trees, capable of producing water flows that are more than just a trickle?

What part (or parts) of a plant is responsible for moving water?

What is the source of energy that must be expended in lifting water?

How do plants pump sap?

These questions, and more like them, have been asked many times; many different answers have been proposed. Yet no one is certain that *the* right answer has been found to any of the questions. Consider the question, "How do plants pump sap?" It is fundamental to the others. Many *hypotheses*, or possible explanations, have been made by professional and amateur scientists. A scientist bases an hypothesis upon the data available and his understanding of the problem. Sometimes little data are available, and the scientists' hypotheses are essentially an "educated guess for some tests."

One hypothesis is based on the same principle that causes liquids to rise in a piece of blotting paper when a corner is touched to the liquid. This phenomenon can be demonstrated in the laboratory by showing that water rises in glass tubes which have small diameters. The smaller the tube, the higher the water rises. Technically this is called *capillary action.* If you cut apart the stem and root of a plant you will find some tube-like structures. Is capillary action the answer to the rise of water in plants? If it is, would the upper branches of dead plants or trees be moist or dry?

A second possible answer pictures a "cellular bucket brigade" with living cells forcing each drop of water up a series of steps. This hypothesis could be based on two facts: (1) Living cells are known to be capable of converting chemical foods to energy, and (2) Energy is required to lift anything upward against the force of gravity or perhaps other related directional forces.

Is the living cell the key? If all the living cells in a band running around a tree trunk were cut away, the leaves would soon wilt, dry up, and die. This suggests that the living cells do serve as a continuous "bucket brigade." But must the cell be living to transport water? What would happen, for example, if all the cells in a tree trunk were killed but left in place?

The scientist Strasburger sawed off a 70-foot oak tree close to the ground. He placed the end of the

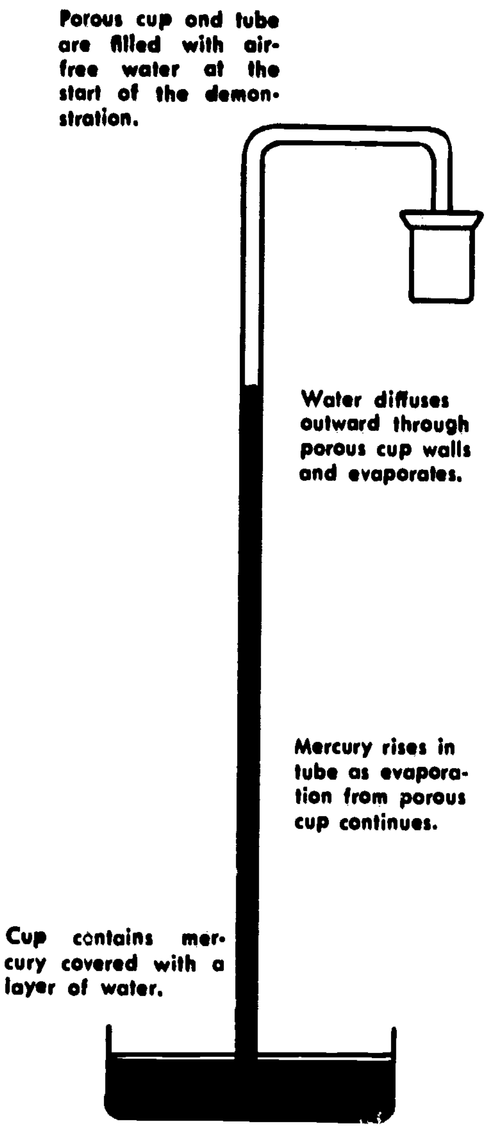


FIGURE 1.

trunk in a solution of picric acid which kills cells on contact. The solution killed the cells as it moved up through the tree. Three days later a tracer dye was added to the solution. The dye was later found at the top of the tree. Does this tell you anything about dead cells or related factors?

Are there sources of energy other than the living cell that might provide the energy required to transport the water upward? The energy of moving molecules is often used to explain the "carrot-and-glass-tube" demonstration and provides a third possible explanation to our problem. A long glass tube is inserted into the top surface of a carrot and sealed in place. The carrot is placed in a beaker of water, and water slowly rises in the tube. The build-up of pressure within the carrot is referred to as *root pressure*. The diffusion of water through carrot cell membranes is called *osmosis*.

When plants are "cut off" several inches from the ground, sap will flow up and out of the cut surface. If root pressure causes the upward motion of water, it is possible for the 300-foot Redwood to develop the 120 pounds-per-square-inch pressure required to raise water to its top branches?

A fourth idea that might provide an answer is the phenomenon of air pressure. Suppose a tube is sitting in a container of water. If air in the tube is removed, the weight of the outside air pushes the liquid up the tube. This is what happens in a soda straw or a mechanical lift pump. If air pressure forces liquids up in plants, how could pressure be reduced inside the plant? If the inside pressure were reduced, how high could air pressure force the sap to rise?

Another possible explanation for sap pumping in plants may be found in the cohesion of water. Scientists have found that water molecules have great attraction for each other. If a long tube of water were subject to a pull at the top, each molecule would tend to lift up the molecule below it. Most of the water that leaves a plant escapes as vapor from leaves, and only a small amount, if any, evaporates from stems. Could the escaping water molecules be the pull required? A model of this has been built in the laboratory (see Figure 1). Evaporation occurs at the outer surface of the porous cup. If the water is absolutely free of dissolved air, the mercury may rise more than 200 cm. Remember that normal air pressure can force mercury up only about 76 cm.

If pull is developed, the water in a tube is under tension—*i.e.*, it is being "stretched"—and only the attraction between its molecules holds the water column together. If tension sometimes exists in the tube-like structures of a tree trunk, what would you predict would happen to the diameter of the trunk? Tree trunk diameters do undergo a cycle of shrinking and expansion every twenty-four hours. Is the "pull-cohesion" hypothesis the answer we have been looking for? If so, how does sap rise in trees in the spring when there are no leaves? What is the source of energy which is used as the sap is moved upward? How is this hypothesis any different from that of capillarity?

Perhaps none of the hypotheses described considers fully all of the observed facts. Once we accept the fact that sap rises in a tree, we realize that there must be an explanation. Considerable time, thought, and experimentation may be necessary, however, before that explanation is found. The rise of sap in plants is not a problem for the botanist alone. Physicists and chemists also may be involved in developing an explanation. Almost any common natural phenomenon can lead to research in a special field of science.

Regardless of background and interests, a high school student can begin with any natural phenomenon, like the rise of sap, and identify a specific project after a period of study and thought. The solution of the problem through intensive library, laboratory, and field research constitutes a science project. A project need not give the complete solution to a problem to be successful. Often the most successful project is one which suggests other research or contributes to the future solution of a problem.

In the following pages you will learn how three students started with the general topic of why and how sap rises in plants and developed worthwhile projects. When you do a science project, you will probably meet difficulties and pleasures similar to those encountered by Colleen, Scott, and Herb.

II. Colleen's Project

Why Do A Project?

Colleen had worked for a florist and regarded gardening as her major hobby. At the florist shop she was taught to cut flower stems held under water before putting the flowers in a vase. She knew that plants deprived of water wilted and that the cutting of stems under water prevented the early wilting of cut flowers. She did not know, however, why a second cutting under water, immediately before placing the flowers in a vase, contributed to their longer life. She felt that the general problem of the wilting of cut flowers could lead to an exciting research project.

Why Read?

Colleen read all she could about water and its effect on plants. High school and college biology and botany texts provided her with considerable information about the structure and functions of plant stems. One fact that appeared particularly significant to the problem brought out that an uninterrupted thread of water from root to leaf was a necessary condition for *transpiration* to continue. She reasoned that plants cut in the air and later placed in water would have developed air spaces in the xylem tubes which would slow the movement of water up the stem. Further reading informed her that the rate of transpiration was influenced by humidity, temperature, kind of plant, time of day, and season. She also found that the speed at which water rises in a stem can be measured with a *potometer*. A text available to her from her instructor's library described the construction and use of this instrument.

Why Define the Problem?

Colleen hypothesized that cut flowers which were not placed in water immediately wilted earlier than flowers whose cut ends were exposed to air for a short period because air spaces developed in the xylem tubes. The air spaces, she figured, hindered the capillary pull of water up the stem. Since the air-clogged xylem tubes should lower the normal rate of water flow up the stem, she decided to test this notion with a potometer by comparing the speeds at which water rises in stems treated in the two ways. Specifically, her problem was: *Is the rate of water flow through the stems of plants significantly influenced by the air exposure of the cut ends of stems?*

Why Use a Systematic Approach?

Colleen decided that several things had to be done before she could proceed with her project. First, she had to identify the plant that would demonstrate well the wilting reaction. She would have to be sure that she could get these plants all the time and that they were not too expensive. Second, she would have to construct a potometer and learn how to operate it.

The next step was to plan the experiment. She decided to test the water-flow rates of ten plants for a forty-eight-hour period. Two of the plant stem ends would not be exposed to air. These plants were called the *controls*. She could compare the results from all of the other plants to these. The stems of the remaining four pairs of plants would have air exposures of fifteen minutes, thirty minutes, one hour, and two hours. Age of plants, temperature, and humidity would be controlled as closely as possible. Colleen estimated that two weeks would be required to find and pretest a satisfactory plant. During the same period she would construct the potometer. She calculated that tests would require twenty days. An additional two weeks would be needed for the interpretation of data and the preparation of a paper and exhibit. Altogether she estimated that this phase of her project would take seven weeks.

Why Is It Difficult to Get Started?

Colleen planned her project enthusiastically. She was anxious to obtain a solution to her problem, and working with flowers had always given her pleasure. Her laboratory skills, however, particularly in fabricating glass apparatus systems, were not well developed. As a consequence, she delayed the start of her project until she developed the necessary skills. Although her science teacher gave her some assistance in bending the glass tubing, Colleen was surprised to find the potometer an instrument easy to construct.

Why Keep Accurate Records?

Before Colleen began to measure the rate at which water flowed through the stems of flowers selected for testing, she prepared a form on which many of her expected observations could be recorded. She included spaces for noting which plant she was using, the type of treatment it was receiving, the date, time of day, temperature, humidity, air pressure, light intensity, potometer readings, and a space for other observations which she could not anticipate. After using the form in a trial run, she copied it onto a duplicating master and ran off several dozen copies. When she completed the sequence of tests she had a neat and convenient record of the data. Colleen found that although the measurements during the first several days of testing were vivid and easily memorized, the mass of information collected by the end of even the first week was easily confused whenever she discussed her progress without referring to her notes. She further found that the final report was greatly facilitated by the full and accurate records she maintained.

Why Keep on the Track?

Colleen determined the water-flow rates twice a day for about three weeks. During school days she made one reading in the morning before school and one reading in the evening after supper. On week ends she began taking her readings later in the mornings and early in the afternoons. After one week's work, she noted that the water-flow rates during the school week were considerably lower than those of the week-end. She immediately thought that her inconsistency in the time of day the readings were taken was a mistake, and she quickly adjusted her week-end schedule. The difference in transpiration rate with the time of day being the only variable, suggested a "biological clock" control of water-flow rate. She recorded this hunch, but successfully resisted the temptation to tackle the new problem.

PARADISE HIGH SCHOOL, PARADISE, CALIF.

Biology students are measuring the rate of transpiration with a potometer made in the classroom.

Why Share Experiences?

At the conclusion of her experiment, Colleen felt that she had discovered a solution to the problem she had proposed. Her science teachers asked her to present the findings before the class emphasizing the *processes* by which they were discovered. The florist for whom she worked recognized that her study had practical values for persons interested in flower arranging. Upon his recommendation Colleen was invited to present her research, emphasizing its practical implications, to the local garden club. The club members were very interested in her work and agreed to help with her expenses as she continued her experiments and research.

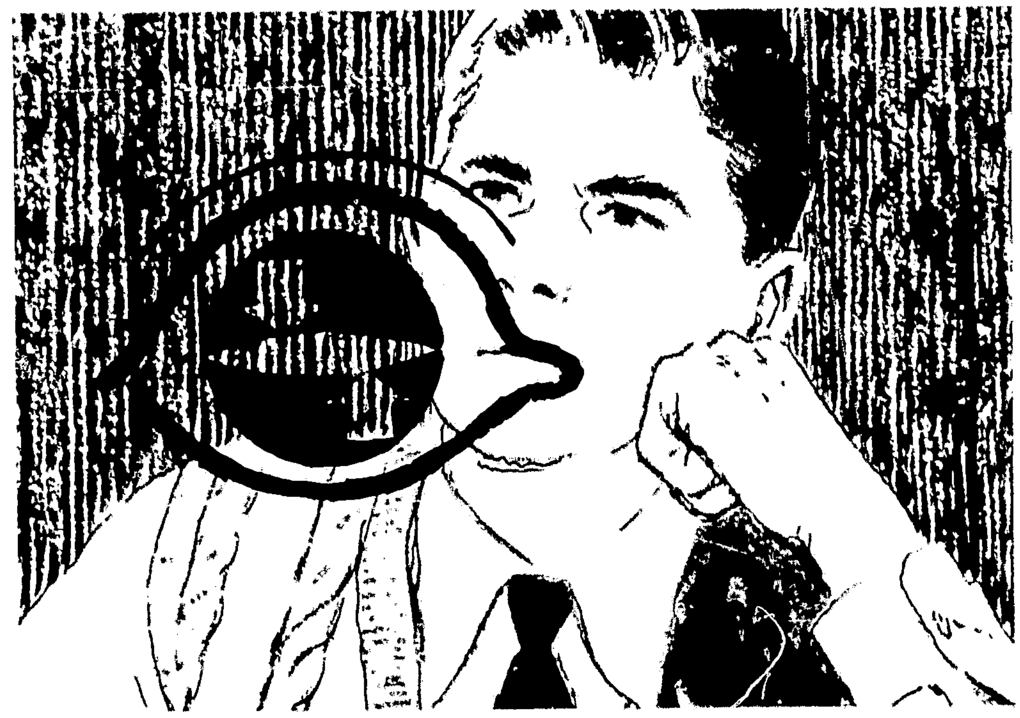
Why Seek Aid?

Colleen was pleased that her project had worked out so well. Yet, she was surprised that the work had raised far more questions than it had answered. She was embarrassed that the class and the garden club members asked many questions about the water relations of plants she could not answer. Her reading on specific topics in plant physiology increased. Now she wanted to answer such questions as:

1. Does the transpiration rate in cut flowers have a definite period?
2. Why should the water into which cut flowers are placed be "as hot as dish water?"
3. What are the quantitative relationships of transpiration rate to humidity, temperature, and light?

Colleen had so many new problems to investigate that she did not know where to begin. Through her county agriculture extension agent she made an appointment with the state agriculture officer in charge of floriculture. When they met, Colleen was well prepared with reading notes and ideas on each of the research topics she was considering as new projects.

III.
Scott's Project



Why Do a Project?

Scott was a natural gadgeteer. For several years he had spent hour upon hour working with automobiles and engines. Before that it was electric trains and erector sets. If it were mechanical, he could fix it.

Scott heard about the "sap-rise" phenomenon in a science class. When his teacher demonstrated root pressure by using the carrot-and-glass-tube device, the results were not impressive—nothing happened. Not until the following day did water actually start to rise in the tube. This seemed a rather slow way of measuring pressure to a young man who was accustomed to measuring cylinder compression pressures on car engines with gauges that gave instantaneous readings.

If scientists wanted to learn more about sap rise in plants, would it be desirable to measure pressures accurately and quickly? Couldn't some device be built to measure root pressure rapidly?

Scott had seen a cloud chamber, a ballistic pendulum, and other student-constructed devices at a science fair the preceding spring. Several of these homemade gadgets had even won awards. Why couldn't an original "root-pressure meter" compete favorably?

Why Read?

When you set out to invent something, it is a good idea to check if it has already been done. Even if it has not been tried, reading may well produce some ideas with which to start. Scott's science teacher told him this when he urged him to take home some physics books. Although he took the books, Scott really thought that his mechanic friend at the garage could fill him in on all he would need to know to begin.

The mechanic showed him the working parts of a gauge utilizing a Bourdon tube. Scott thought it looked complicated and wondered about its construction. The mechanic said that if two devices could do the job equally well, the simpler would be better—there would be less that could go wrong —but he coudn't tell him much about "why the gauge worked."

In reading the pressure sections of the physics books, Scott gained some knowledge about pressure and the terminology associated with it. Following his father's suggestion he went to the town library and found a book on scientific instruments. It seemed rather old and outdated but he signed it out. From the book he learned that manometers and barometers are common devices to measure pressure. He also found a description of an osmometer to measure osmotic pressure which sounded like the root pressure discussed in class.

Why Define the Problem?

Scott was all set to start building an osmometer as described in the book. The drawing was rather simple and the parts would be easy to find in the school laboratory.

He made up a list of the equipment needed and presented it to his science teacher one morning before school. Instead of being overjoyed at Scott's progress, the teacher told him that he would have to define a specific problem before the equipment would be available. This seemed rather silly to Scott because *he* knew what *he* wanted to do although it was a little difficult to put it in words.

After a five-minute lecture on the values of specifically stating a project problem, Scott agreed to prepare a statement although he was not entirely convinced of the procedure. Later that morning he started to write the statement. He showed it to Miss Stewart, his English teacher, and she helped him with the final summary of the problem.

The statement Scott presented to his science teacher after school was, "*How can small root pressure changes be measured accurately and quickly?*" It was accepted by the science teacher.

Why Use a Systematic Approach?

Scott realized that his project work would be separated into three principal phases. First, he would design his device. Second, he would construct it. Third, he would use it to measure various pressures to evaluate its sensitivity and range of application.

The science teacher urged Scott to set up a time schedule for each of the three phases. Scott thought that since genius could not be hurried, a schedule would be useless. He did agree with his teacher, however, on a target date for completing the project. The proposed time was ten weeks. Mentally he figured that would give him three weeks for each phase, plus one week for unexpected difficulties.

Why Is It Difficult To Get Started?

Scott had read about several devices to measure pressure. Each of these worked, yet none was exactly what he had in mind. One week after deciding on his problem his teacher asked for a progress report. Since Scott felt he had not made much progress, he conferred with his teacher. Together they decided that a method was needed to magnify the small motion of a thin diaphragm sensitive to pressure changes.

As a source of ideas, the teacher put Scott in touch with a mechanical engineer at a local industry. After listening to Scott's problem, the engineer described a device known as an optical lever. The device was simple and Scott could see how it would do the job. The problem was solved.

Why Keep Accurate Records?

Scott began to construct his device at school as soon as he had sketched a plan for it (see Figure 2). His science teacher suggested that Scott keep notes on his progress. Scott was too interested in his invention to argue, so he started to keep a diary-type notebook similar to the one the engineer had been using for his research. Each day he recorded progress, difficulties of construction, and sketches of other ideas that occurred to him. When the device was completed, he planned to record performance and calibration data.

Why Keep on the Track?

By now Scott had a name for his device—an optical manometer. While constructing it he got the idea that it might be used to measure slight changes in air pressure as well as root pressure, as originally intended. He also thought of several ways to improve the device even before it was finished. Since his original ten-week target date was getting close he avoided getting side tracked and filed the ideas in his notebook for future reference and study.

Why Share Experiences?

When Scott's optical manometer was constructed and tested, he decided it was good enough to enter in the local science fair. His science teacher told him that just the manometer would not be enough. In order to understand the device, most people would need an explanation of what it was, how it worked, and why it was worthwhile. Scott decided that he would write up his work completely and enter it in the Future Scientists of America Awards program of the National Science Teachers Association. He also prepared a display for the science fair.

After preparing for both competitions he expressed the feeling that he was ready to take a place alongside Edison, and the teacher calmly noted his excitement.

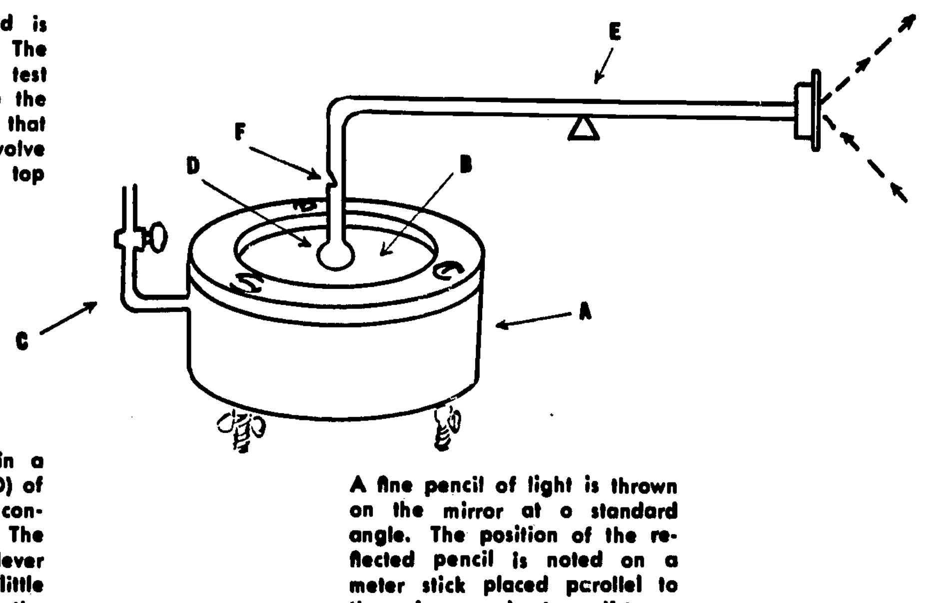
Why Seek Aid?

Scott felt that his project was all of his own doing—which it was. But his mother pointed out that he was fortunate to have had help from several sources, especially his science teacher. He began to realize that he had received considerable aid not only from his teachers, his parents, an old friend, a new friend, but the authors of the books he had read. He resolved that when he did a project next year, he would seek help and advice even more actively. Scott confided his plans to the science teacher who offered support.

FIGURE 2.

The solution to be tested is placed in the flat cylinder. The top plate (A) holding the test membrane (B) is bolted to the cylinder. Care is taken so that no air is trapped (relief valve C). A gasket seals the top piece to the cylinder.

Pure water (or other liquid) is poured in the battery jar to a level indicated by a notch (F) on the optical lever.

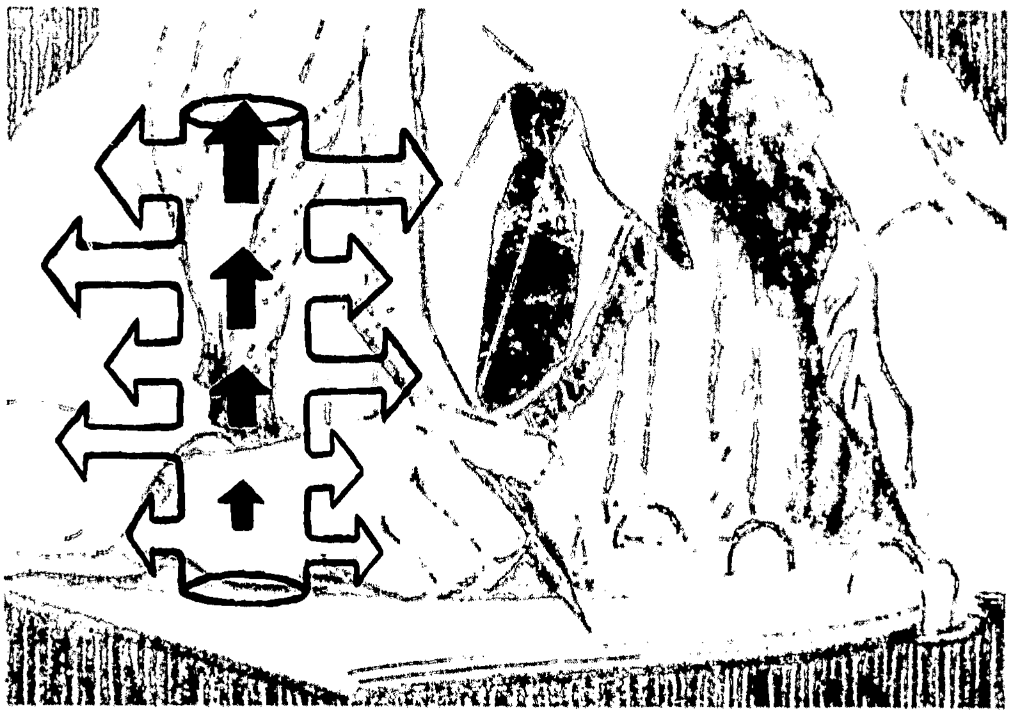


The apparatus is placed in a battery jar and the knob (D) of the optical lever placed in contact with the membrane. The pivot point (E) of the lever is so positioned that little net force is placed on the membrane.

A fine pencil of light is thrown on the mirror at a standard angle. The position of the reflected pencil is noted on a meter stick placed parallel to the mirror and at a distance of one meter.

As osmosis proceeds, the diaphragm will "bulge" up or down depending on the liquid flow. The motion is magnified by the lever, and the spot of reflected light is moved. The amount of movement is proportional to the amount of "bulge."

IV.
Herb's Project



Why Do a Project?

When it came to science, Herb had a reputation for being a good student. One day a fellow student asked Herb why sap moved upward in trees. Herb had seen a brief comment on the phenomenon in a Sunday newspaper feature section, but that did not provide a complete answer. He answered by saying that he did not know, but would have the answer the following day to clarify the question.

A quick reading of a college text on plant physiology gave the usual possibilities—capillarity, root pressure, etc., but none satisfied Herb. The next morning, Herb gave the "accepted" pull-cohesion explanation. He had some personal reservations about the theory, but after all, he did have a reputation for knowing all the answers.

That night Herb read further in the plant physiology text, then turned to a physical chemistry book for more information about osmosis and capillarity. He encountered a description of electro-osmosis almost by accident. In this phenomenon, liquids move through small tubes when an electrical potential difference is applied across the tube.

He read more and found that when liquids are forced through small tubes a potential difference is established across the tube. Technically this phenomenon is called streaming potential. At the time Herb did not quite realize that he was beginning a research project. Both of these effects, electro-osmosis and streaming potential, were destined to be very useful in his research.

Within a few days, Herb was very excited about the rise of sap in plants. No textbook gave a satisfactory answer. Many physical effects were known, but no one was sure of their relationship. Here was a chance to explore the unknown.

From previous projects, Herb knew that the experimental investigation of questions without the ready-made answers was enjoyable and rewarding. The rise of sap in plants was such a common, and yet important phenomenon that it deserved a better explanation than he had been able to find. Herb was "hooked." He had to investigate the rise of sap in plants.

Why Read?

Reading to gain information was easy for Herb. He read other plant physiology and physical chemistry texts. He checked the *Readers Guide to Periodical Literature* for references to magazine articles in *Scientific American* and *Science*. The topics he looked under were ascent of sap, osmosis, electro-osmosis, streaming potential, capillarity, and water transport in plants.

In searching for further sources of information, Herb wrote a letter to the chairman of the botany department of a nearby university. He described his interest and requested advice on obtaining more information. A reply was received from a specialist in biophysical chemistry to whom the letter had been referred. The specialist invited Herb to visit him on the campus, and he quickly accepted the invitation.

Why Define the Problem?

The evening after receiving the visit invitation, Herb had just started his homework when, *Flash*, it happened—a new idea to explain the rise of sap. It took only one pencil, one sheet of paper, and twenty-one minutes to get the idea written. It took another five minutes to dignify the hypothetical explanation with the title, "The Autoelectro-osmosis Hypothesis." Essentially the hypothesis was as follows:

> Assume a small vertical tube in a tree (a tracheid).
>
> Assume the tracheid is filled with water. Water diffuses outward through the tracheid walls. The diffusion produces an electrical potential difference between the inside and outside of the tube wall (streaming potential). Assuming the diffusion is more rapid at the top of the tube, the potential difference will be greater at the top. If this is true, a *potential difference will exist between the inside top and the inside bottom of the tube.* From the known phenomenon of electro-osmosis, an upward liquid flow will be initiated in the tube by this potential difference.

Herb's anticipated conference with the scientist specialist was rewarding. Herb was surprised at the scientist's avid interest in the same problem and also pleased when he heard that there was no good reason why "The Autoelectro-osmosis Hypothesis" could not be proven valid.

In discussing the hypothesis, Herb realized that the scope involved was greater than he could hope to investigate in one school year. His scientist friend pointed out that there were several specific problems leading to a final and conclusive test of the hypothesis. These smaller parts of the total problem could be investigated with the time and facilities available to Herb. The specific problems agreed on were:

1. How is the electro-osmotic flow rate affected by the magnitude of the potential difference?
2. How is the streaming potential affected by the rate of osmosis?
3. How are streaming potential and the electro-osmotic flow rate affected by the nature of the membrane through which flow occurs?

Both agreed that each question should be answered quantitatively. Before Herb completed his discussion with the science specialist, they designed an apparatus that could be used for each of the specific investigations (see Figure 3).

Why Use a Systematic Approach?

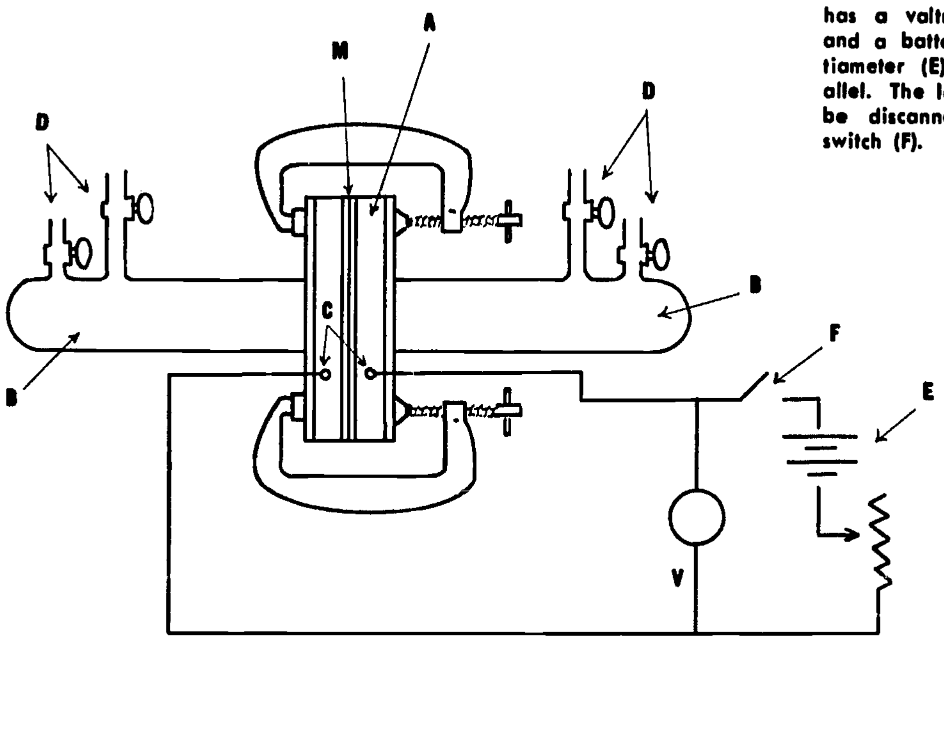
Herb, realized that a great deal of work had to be done. He did not think it was practical to set a time schedule, but he wrote an outline to show the order in which things would need to be accomplished. It read as follows: (1) Construction of apparatus; (2) Find workable solutions and diaphragm; (3) Record flow data when all conditions except voltage are constant; (4) Record voltage when all conditions are held constant except flow rate; (5) Repeat (3) and (4) with different diaphragms and solututions; and (6) Write a summary of findings.

FIGURE 3.

The central membrane and gasket assembly (A) joins two glass tubes (B) with the test membrane (M) between. Three C-clamps at 120-degree separation are used. Electrical contact with the solutions on opposite sides of the membrane is made through connections (C) and the metal halves of the gasket assembly. Electrical contact between the metal halves is prevented by insulating gaskets.

Two access tubes (D) with stopcocks are attached to each glass tube. These facilitate filling with liquids, permit escape of trapped air, and allow manometers or other pressure gauges to be attached.

The electric circuitry has a voltmeter (V) and a battery-potentiometer (E) in parallel. The latter may be disconnected by switch (F).



As part of his attack on the general problem, he would extend his readings to search for information on electrical potentials known to exist in plants.

Why Keep Accurate Records?

Herb now had a promising project problem, a strong reading background, the personal advice of a professional scientist, and a sound plan of attack. He was already and eager to start work—but, he did not. First, as president of his class, he became involved in helping to plan a Parent Teachers Association meeting. In addition, it seemed as though all his teachers were "piling on" the homework, and by carrying five academic subjects, the work was never ending. Then the swimming coach decided that Herb's backstroking ability could produce a championship if Herb would work out an extra half-hour each day. With Herb's Saturday job at Bateman's TV Repair Shop, where was he to find time for project work? The weeks flew past, and eventually he began to work.

From previous experience, Herb knew the value of recording every piece of observational progress. With the pressure of time-demanding activities, a thorough record was even more necessary since there were stretches of ten or more days when no time could be spared for work.

Altogether Herb's system of keeping records consisted of three phases: (1) He maintained a daily log of progress; (2) He kept a card index of the books and articles he read along with summaries of the relevant facts obtained; and (3) He set up tabular forms to record specific experiment results.

Why Keep on the Track?

As Herb's work progressed many interesting side questions arose. Typical of these were: Exactly how fast does sap flow in plants and in individual tracheids? What do biologists know about the movement of liquids in and out of cells?

These questions did not divert Herb since he had a ready-made place for them. He wrote each on a card which was then added to his cumulative file of reading. If a certain article were pertinent, he noted the reference on the question card with other notes.

Many short informal conferences with his science teacher assured Herb that he was concentrating on the proper aspects of his project. His science specialist friend also came to the school to talk to the science club. After the club meeting, he met with Herb and was pleased to learn of his progress. He also encouraged Herb to keep up the good work and suggested that the experimental apparatus be photographed and included with the experiment data.

Why Share Experiences?

The experimental work was completed just before spring vacation. Herb made use of the extra time to analyze his results and think about their implications. He found that the results were closely consistent with his original idea, "The Auto-electro-osmosis Hypothesis." The only big question in his mind was: "Are living plant membranes analogous to the membranes used in the experiment?"

Herb then set himself the task of writing up his hypothesis and preliminary investigations. He did this for two reasons. First, this is the way scientists communicate. Second, he felt that writing his ideas and observations in a logical order would clarify them in his own thinking and form a sound basis for further work. Herb recalled that someone once said, "An idea is not real until it is communicated to someone else."

Once the paper was written, several copies were needed. A copy was sent to the science specialist who had helped him. One was placed in the school's science library. Another copy was submitted to the state Junior Academy of Science. An original was sent to the Future Scientists of America Awards Competition.

Why Seek Aid?

At the school's spring recognition assembly, Herb was asked to speak briefly on his research. He modestly gave much of the credit for his success to the aid he had received from several sources. Outlining his method in an approach used by scientists, he classified the ways he had been helped into four categories. They were:

1. Reading knowledge had been supplemented.
2. Experiment techniques had been developed.
3. Assumptions had been confirmed.
4. The feasibility of his project had been assured.

V. Recognition

Reporting Your Project

Practicing scientists even from the very earliest periods of scientific enterprise have liked sharing their work and the results of their investigations with other people. We hope future scientists will not be content simply to tell other people about their projects, but will write them up for publication or prepare displays based on their projects for school and regional science fairs. Another reason for writing a report of your work is to prepare it for presentation at a student science congress.

These are some of the questions a student should ask himself as he prepares a report of his project!

1. What did I try to do? Where did I get the idea for this project?
2. How did I do what I tried to do? Why did I take this particular approach to my project?
3. How successful or unsuccessful was I? How could I have been more successful? Am I sure what I found out is accurate? How could it be wrong?
4. What good has come from my attempt to work on this topic?
5. What is the next project I would like to work on?

Although industrial and government laboratories provide their research men with detailed directions for reporting projects, in general, they avoid printed forms or "fill-in-the-blanks" reports. For this and other reasons, we present here only a suggested outline. The outline provides direction but, at the same time, it allows the student freedom of expression as he prepares the report of his project.

TITLE

I. Summary.
  A. Topic or problem investigated.
  B. The purpose of or reason for the investigation.
  C. The most important results or information gained from the investigation.
  D. Suggested action based on the results of the project.

II. Discussion.
  A. Circumstances leading up to the project.
  B. Acknowledgement of help received from other people.
  C. Methods used in making the investigation.
  D. Conclusions and the reasoning upon which these conclusions are based.
  E. Argument for the suggestions or recommendations which grew out of the project.

III. Appended Materials.
  A. Drawings, photographs, graphs, tables, maps, calculations, and other evidence supporting the project report.
  B. Other material dealing with the project.

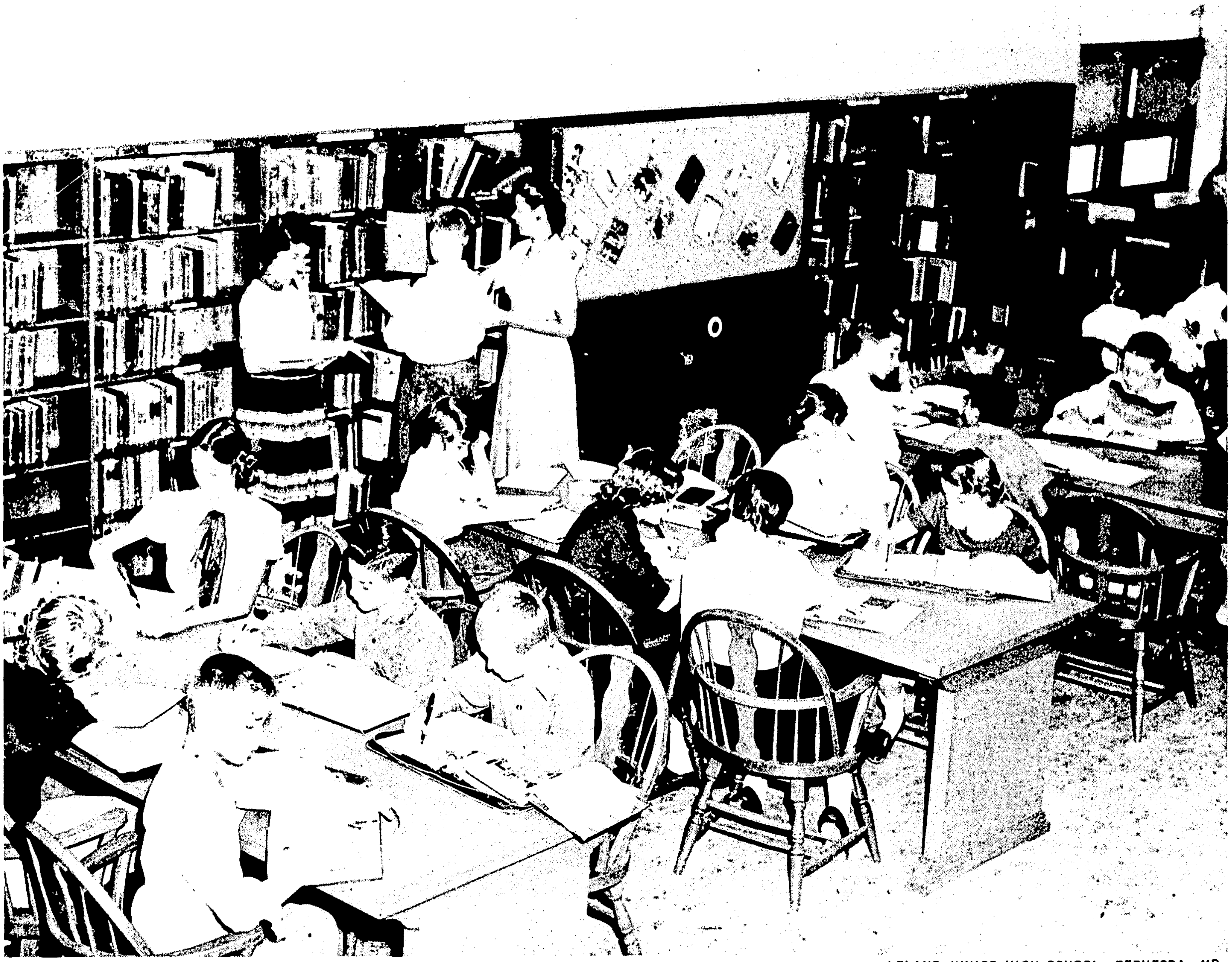
What To Do with Your Report

There are many different ways in which you can gain recognition for your work. Your own school is the first place. Your class or club will want to hear your report. Your teacher can tell you about local and regional science fairs and congresses. Other sources are listed.

Future Scientists of America Awards. Various awards are given to students in grades 7 and 8, 9 and 10, 11 and 12. There are eleven geographical regions with separate awards in each region and in each grade division. Award winning papers are published in *Science World.* Information can be obtained from Future Scientists of America, National Science Teachers Association, 1201 Sixteenth Street, N. W., Washington 6, D. C.

Science Fair International provides cash, equipment, and medal awards to finalists. Competition in the international fair is limited to students in grades 10, 11, and 12 who have participated in a local science fair conducted by Science Service, Inc., of 1719 N Street, N. W., Washington 6, D. C. In addition, Science Service, Inc., the journalism profession, and many other science related groups sponsor the National Science Fair.

Westinghouse Science Talent Search provides about $35,000 in scholarships and some forty all-expense trips to a five-day Science Talent Institute in Washington, D. C. It is limited to graduating high school seniors who score high on a competitive examination and complete a project report. More information concerning both Westinghouse Science Talent Search and Science Fair International may be obtained from Science



The teacher in the background visits the library with the science class as they begin research on the various projects of their choice.

Clubs of America, Science Service, Inc., 1719 N Street, N. W., Washington 6, D. C.

Junior Academy Fairs and *Congresses* are another major source of recognition. If you do not have an affiliation with your state Junior Academy, you may get in touch with your state group through the American Association for the Advancement of Science, 1515 Massachusetts Avenue, N. W., Washington 5, D. C.

There are many other specialized programs which may operate in your area. Ask your teacher and watch the bulletin notices in your school. A good project is worth as much recognition as possible in local or national outlets.

PART TWO
Project Ideas

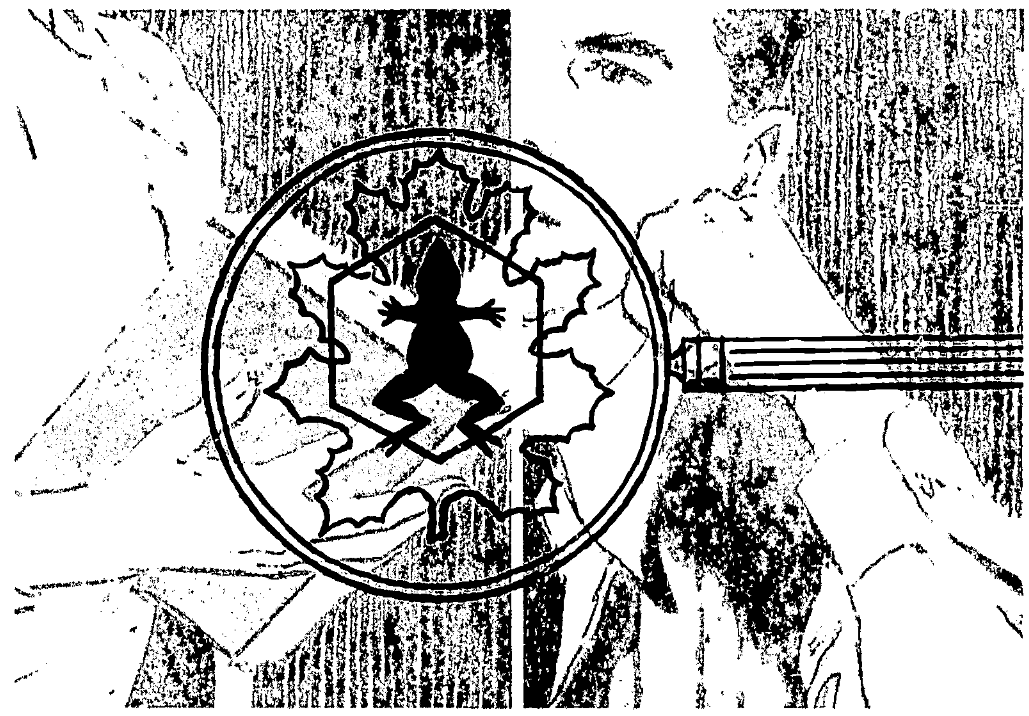
A project begins with a question about a phenomenon. On the following pages many phenomena are called to your attention. Each includes a number of problem questions intended to make you think about how they can be solved.

Some students may wish to undertake research projects beginning with these ideas. Other students may ask their own questions about the phenomena. Some of you may even identify problems in phenomena not described in this compilation.

Do not look for step-by-step instructions to follow. Every sentence in Part Two, if not followed by a question mark, is intended to lead you to a question. Your own ideas, reading, and experimental work will contribute more to the success of your project than anything in these pages.

For convenience, the project ideas are grouped into the fields of biology, chemistry, physics, and general science. Experimental science, however, pays no attention to the science discipline boundaries. Many of the project ideas, regardless of their classification, should appeal equally to physical and biological science students.

VI. Biology



Aging and Life Span

Life span is one of the characteristics associated with species. As organisms age, they appear to lose vigor and die. The maximum life span of man is approximately 115 years. For animals, it differs. The toad, for example, has a life span of 35 years, while the rat spans only 4½ years. The process of aging is complex; many factors contributing to the causes. The life span of wild birds in the field is considerably shorter than the same species of birds that are maintained in captivity. Here, the controlling factor appears to be the rigors of environment. Under carefully controlled laboratory conditions, however, planaria which are alternately starved and fed survive longer than those which are steadily well fed.

In testing the factors which control or influence the life span of an organism, be certain to select specimens whose life spans are short enough generally that sexual cycles can be observed. Fruit flies and water fleas are good subjects.

1. Do long-lived parents produce long-lived progeny? What is the genetics of longevity? Is the trait of longevity expressed by physical characteristics?

2. Can life spans be significantly prolonged or shortened when diet, temperature, light, or atmosphere are altered?

3. Do the offspring of younger parents tend to live longer than the offspring of older parents?

4. Is the life span of one sex greater than that of the other sex?

5. What structures or processes of organisms reflect their age? How well can these be measured quantitatively?

6. Does aging affect mental processes? A popular phrase says, "You cannot teach an old dog new tricks." Is this true of man and other organisms?

7. Does the size of an organism affect its life span?

Animal Banding and Marking

Bird marking is an extensive research technique in the United States. Since the Fish and Wildlife Service began its program in 1920, over nine million birds have been banded. From the birds recovered, considerable information has been gained on the migration, dispersal, and age of wild birds. Bats, rabbits, deer, fish, and other organisms are marked for purposes of gathering data. You could use these techniques to try to discover:

1. How far a chipmunk will range from its nest. Set out live traps in increasingly greater distances from its nest.

2. If land turtles, released miles from their water holes, will return to them.

3. The annual growth rate of snakes.

4. The number of years that frogs survive in the wild.

5. Whether ants of the same species are acceptable and adaptable in nests of another queen mother.

6. Whether migrating monarch butterflies survive the winter and return to the same area the following summer.

Animal Learning

The ability of certain animals to learn to run through mazes has often been demonstrated. Follow-up questions a researcher might ask are:

1. What senses do animals use in learning a maze? Does a mouse learn to smell, hear, or feel his way through?

2. Can a pregnant female transmit to her young the ability to learn a given maze faster than she or other young mice are able to learn the maze? Can a mother teach a litter to learn a maze?

3. After an animal is able to learn one kind of maze, can it learn other kinds of mazes faster?

4. What effects do factors such as noise, strong magnetic field, infrared light, slope of maze, wind, distracting aromas, vibration, etc., have on the learning of a maze or the recall of learning?

5. Do young animals learn mazes faster than older animals? Do young animals forget learning faster than older animals?

6. Is there one best level of reward for animals in the process of learning? Specifically, what is the optimum quantity of food necessary to teach a dog to roll over?

Behavior Patterns

Many behavior patterns of organisms appear to be controlled in a manner quite similar to the guidance mechanism of missiles. The performance of a missile in reaction to foreseen conditions is coded into its regulatory system or "brain." Various kinds of missiles have different purposes, different structures, and different coded instructions. No two missiles of the same kind behave identically. The parallel among organisms seems to be observable in the reaction of a fly to light. When a house fly is released in a room darkened with the exception of one window, it will probably fly to the window and may spend the rest of its life there apparently trying to get through. Coded into the fly's behavior pattern is this positive phototropism, but not coded into the fly's behavior pattern is recognition and reaction to glass. Behavioral patterns can be explored in various ways:

1. Web-building spiders produce an observable and preservable pattern of behavior.

   a. How does the web pattern of an individual spider vary with such factors as age, hunger, thirst, wind, and consistent sabotage?

   b. Can a spider finish the partially completed web of another spider?

   c. Do all members of the same species of spider produce identical webs?

2. What are the conditions of light which control the sleep movements of plants such as the sensitive plant or beans?

3. Do humans exhibit any common, inherent, and complex patterns of behavior in reaction to stimuli? Are war, competition, or maternal love coded into the behavior of man?

4. The pattern of germination and growth in plants is greatly influenced by the gravitational field. What are the effects of "frustrating" the response by increasing the gravity, periodically lowering it, and constantly changing the axis through which gravity acts?

5. Do the roots of plants exhibit a special tropism when the stems are stimulated by a constant wind?

Study of Cilia

Cilia are delicate, hair-like cellular structures in incessant vibratile motion. They are common to most animals and some plants. Cilia function in the processes of locomotion, ingestion, clearing tubes of debris, and directing eggs into Fallopian tubes. The rhythmic action and structure of living cilia can best be observed under a microscope with a stroboscopic light source. The flow patterns of ciliated tissue on the tongue of a frog can be observed by plotting the paths taken by small pieces of cork placed on the tongue. Ciliated cells are fascinating to observe and are a source of puzzling questions for the researcher in physics, chemistry, or biology.

Deduction Studies

Is a bird's nest a dossier? Can information about the structure and habits of a bird be deduced from the size, shape, locality, materials, debris, and other observable clues to be found in an abandoned bird's nest? Similarly, with what accuracy can organisms be reconstructed with only one or two clues on which to base a reconstruction? For example, how much information do you have about a human when only a hand is exposed to observation? How can scientists reconstruct a dinosaur skeleton when only part of the skeleton is found?

Earthworms

All organisms have one outstanding characteristic in common —*life.* To uncover biological secrets of one organism is to discover unknowns about all living things. It is desirable, therefore, to select as subjects for research, organisms which are abundant, inexpensive, available during all seasons, easily cared for, and not subject to emotional attachment. The earthworm is one such organism.

After mastering the general anatomy and physiology of the earthworm, the researcher can direct his efforts to discovering solutions to such problems as:

1. Does an earthworm emerge from the soil after a rain to avoid drowning?

2. How can the mode and rate of locomotion and the mode and rate of total body response to traumatic stimulation be explained?

3. Can an earthworm regenerate a normal whole after being severed behind its clitellum?

4. How does the pulse rate of the dorsal blood vessel vary with temperature?

5. What are the temperature tolerances of worms?

6. Since no endrocrine system is known for earthworms as *yet,* how do earthworms respond to hormones such as adrenaline or insulin?

7. How do earthworms respond to stimuli such as light, acidity, temperature, sound, direct electrical current, etc? Are the senses distributed evenly throughout the body?

8. How does the blood of an earthworm compare with human blood, structurally and chemically, and other ways?

9. What parasites infest the earthworm?

Fence Row Ecology

Early in the history of the United States property lines were marked with hedge rows, stone fences, stumps, or rail fences. In each area cleared land was surrounded by the kind of material that provided abundant shelter for wild life. With the invention of clean wire fencing which conserved crop land and was easy to construct and maintain, wild life was allowed little more than grassy shelter. These wire fences were claimed to be effective in con-

An after-school research team works in the laboratory examining cultures to determine their condition.

trolling insect pests and weeds. Recently conservationists have been urging farmers to plant living fence rows of multiflora rose, red cedar, bush honeysuckle, and other plants depending upon the soil, climate, and wildlife needs for survival.

1. How effective are shrub fence rows compared with sod (wire) fence rows in regard to the number per linear mile of beneficial insects (ladybird beetles), injurious insects (locusts), nesting birds (bob whites), harmful small mammals (rabbits), and beneficial small mammals (shrews)?

2. Where shrub fence rows are not wanted, to what extent can sod fences be improved for wildlife by growing sweet clover or *Sericea lespedeza*?

3. To what extent do shrub fence rows affect adjacent crops by shading or by sapping soil moisture?

4. In your area what plants make the best kind of shrub fence row?

Hair

In general, every human society maintains an interest in the way hair is styled. Whether it is physically or chemically altered, hair is an element of beauty. Hair is the habitat of many plants and animals. To the criminologist, hair is a means for the identification of individuals and species of mammals. The role of mammal hair in our economy extends from violin bows and woolen blankets to home permanents and combs. Considerable research can be focused upon hair:

1. Which grows faster, in man, body hair or scalp hair?

2. How do the following hair properties compare microscopically?

a. Blond hair and brown hair.

b. Eyebrow hair and scalp hair.

c. Albino hair and gray hair.

d. Dyed or bleached hair and naturally colored hair.

e. Curly hair and straight hair.

3. How is the metabolism of the normally hair-covered mammal affected when the animal is shaved?

4. Is the tensile strength of hair reduced after it has been bleached?

5. Can hair be stimulated to grow faster?

6. Is hair an effective organic plant fertilizer?

7. How does a fingernail differ from a hair? What is a horn?

8. What are the effects of alcohol, lanolin, greases, shampoos, depilatories, and similar cosmetics on the manageability, growth stimulation, and other advertised reactions of materials on hair?

9. Do widow's peaks or hair on the second segment of the fingers follow Mendelian genetic laws?

10. What are the growth patterns of hair in the nose where a filtering function is indicated?

11. Do body hair patterns indicate that hair originally grew out from between scales?

Metamorphosis

The hormonal control of metamorphosis can be investigated directly in insects and frogs. The location of the controlling endocrine gland(s) can be determined by tying a knot around the body of fly larvae at various locations so that body fluids cannot pass through the constricture. Since pupation should occur only where the metamorphosis hormone is supplied, constricting a number of specimens, each in a different location, should locate the hormone source. Change in body form of frogs from tadpoles to adults can be greatly accelerated by including thyroid and iodine in the diet of the tadpoles.

Additional problems might concentrate on the internal location and histology of the insect larvae glands, the effects of the removal of the thyroid gland in tadpoles, a study of insecticides which reportedly prevented the maturation of preadult insects, and the effects of additional thyroxin or pituitrin on the growth of animals that do not undergo metamorphosis.

References are listed:

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C. M. Williams. "The Metamorphosis of Insects." *Scientific American*, 182:24. April 1950.

Mold Control

With the exception of certain cheeses and antibiotics, man's economic relations with mold are not friendly. The results of mold action include property loss, foul odor, and toxicity. Food and other materials are treated chemically, dried, cooled, and covered to prevent or retard the growth of these plants. Better ways are sought constantly of controlling mold by thorough observations of their specific humidity, temperature, and nutrient requirements.

1. Bread manufacturers take a number of measures to reduce mold growth. What is the comparative effectiveness of bread additives such as sodium diacetate or calcium propionate? Is packaged white bread more resistant to mold than unwrapped pumpernickel?

2. The United States Government lists among needed inventions a permanent mold-prevention treatment for clothing. Why should this be such a problem?

3. What is the critical temperature-humidity index that must be achieved if basements are to be maintained mold-free and comfortable?

4. Critical in the world's food problem is the decreasing availability of nutrient protein. Do molds growing on carbohydrates produce usable protein?

5. Are certain commercial fungicides more effective on the mycelium stage or spore stage of specific groups of fungi?

6. How do molds respond to various frequencies of light? Is ultraviolet light as effective in mold control as it is for bacteria?

Natural Selection

The force in evolution is termed natural selection. How selection operates on a geological time scale is a difficult area of research. The effectiveness of specific selective factors on specific populations of organisms, however, can be tested.

1. What selection occurs in cages containing mixed populations of vestigial-winged and fruit flies under conditions of calm air and under conditions where a breeze passes through the cage?

2. What selection through competition results between two species occupying the same environment, as in mixed populations of *Paramecium caudatum* and *Paramecium aurelia* or guppies and swordtails?

3. Will sparrows feed more readily upon corn spread out on a black background than corn protected by being placed on a yellow background?

4. Can strains of insecticide-resistant flies, or antibiotic-resistant bacteria be developed in the laboratory?

For a reference, see F. J. Ryan. "Evolution Observed." *Scientific American*, 189:78-82. October 1953.

Photoreactivation

When bacteria are exposed to ultraviolet light, mutation, inactivation, or death may result. A strange phenomenon may be observed when, after an otherwise lethal exposure to ultraviolet light, a white light beam is directed upon the "doomed" bacteria. A high degree of survival is observed. This reversal of reaction to ultraviolet light by the addition of white light is termed photoreactivation.

1. What is the maximum dose of ultraviolet light from which the bacterium *Escherichia coli* can recover by photoreactivation?

2. Must the photoreactivating light be white?

3. Do organisms such as salamanders, crickets, or earthworms react as do bacteria?

4. What is the nature of the biological damage caused by ultraviolet light that can be reversed by lower energy electromagnetic radiation?

For reference, see Joe W. Tyson. *Atomic Radiation in the High School Science Class*. Oldfriends' Books, Austin, Texas. 1959.

Plant Pigmentation

Do all flower pigments react to acids and bases by showing color changes? What are the effects of different concentrations of acids and bases on plant pigments? Is it possible to tell the pH of soil by the color of flowers of a pure strain of petunia? Can the pigments of plants be changed by the addition or removal of trace elements in the soil? Can the autumnal coloration of leaves, the unmasking of existing pigments, and the synthesis of anthocyanins be induced in plants at any time during the growing seasons? As revealed by chromatography, how many different pigments are there in the many strains of one species of flower as compared with the parent wild stock?

Plant Virology

Tomato or bean plants can be given a virus injection by brushing their leaves with a mixture of cigarette tobacco, Carborundum, and water; or ground potato eyes, Carborundum, and water. The resulting infection shows up as local lesions and a mottled appearance on the leaves. It is interesting to note that when freshly mascerated spinach is added to the inoculant, the virus injection is lessened.

1. What is the ingredient in spinach that apparently inhibits the action of the viruses?

2. How can one be certain that the disease is caused by a virus and not a bacteria or fungus?

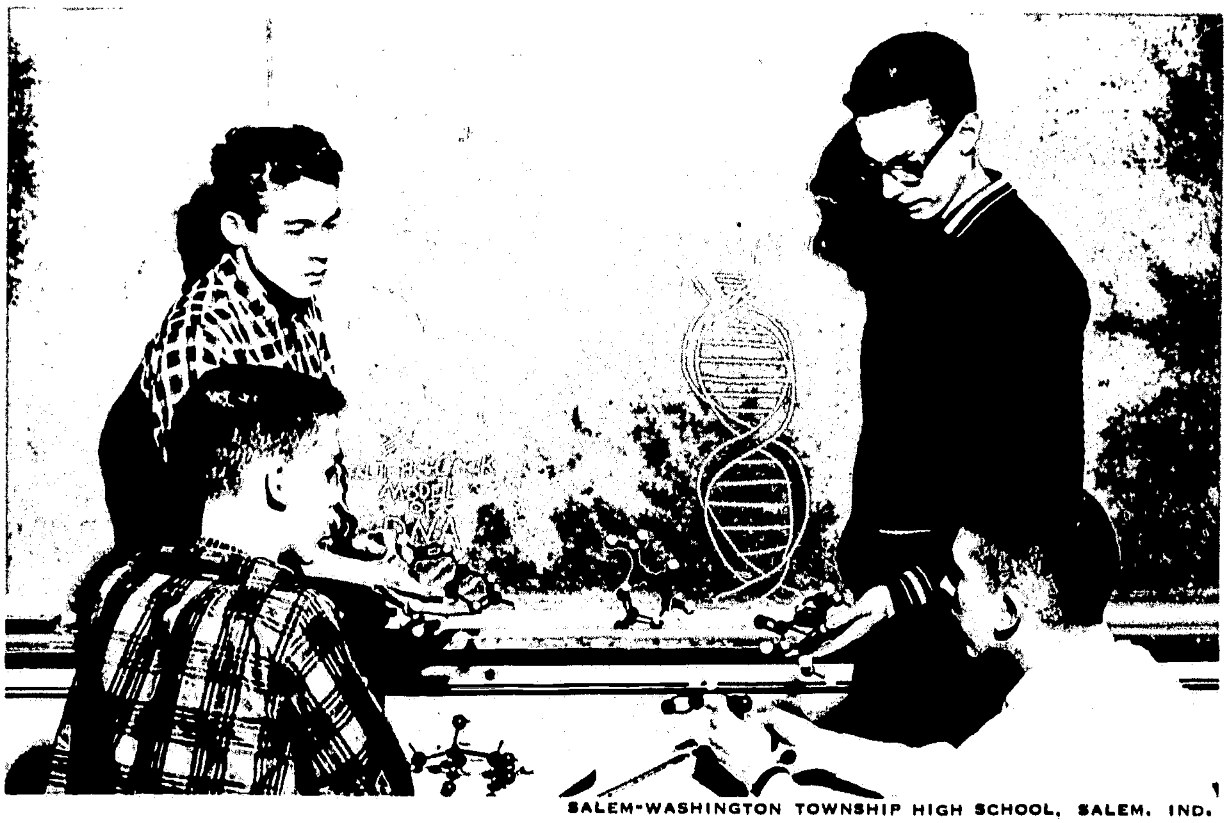
3. Is it conceivable that the disease was induced by the creation of conditions under which a particular gene expressed itself?

4. Should smokers wash their hands before handling tomato plants?

For reference, see the "Report of 1954 West Coast Science Teachers Summer Conference." *The Science Teacher,* 12:25-40. February 1955.

Population Genetics

A certain human genetic trait can be the subject of extensive research in heredity and population genetics. Observable traits such as ABO blood types, ability to taste PTC, and eye color enable one to learn how the traits are inherited and what are the probable genotypes of unobserved and heterozygous persons. One of the most challenging questions that can be asked



Following a visit to one of the research laboratories doing research on population genetics, the teacher and students initiated a study of the culture *Tribolium.* This involved considerable discussion about chemical structures and weekly seminars were set up to go over the material before proceeding in the laboratory.

concerns the frequency of a particular gene in a population. For example, within the gene pool of the American population what is the percentage of occurrence for the nontasting gene? Does interbreeding of subgroups within a population show differences in gene frequencies? Can mathematical models be constructed to show how gene frequencies change under the influences of selection, migration, and mutations. Can the observed phenomenon of genetic drift be duplicated with a shrinking model population?

For references, see T. Dobzhansky. *Evolution, Genetics and Man.* John Wiley and Sons, Inc., New York. 1955.

A. M. Serb and R. D. Owen. *General Genetics.* W. H. Freeman and Company, San Francisco, California. 1952.

C. Stern. *Principles of Human Genetics.* W. H. Freeman and Company, San Francisco, California. 1949.

Population Pressure

If a pair of flies were mated after the last frost in spring and all the resulting young mated at maturity, and this cycle continued until the first killing frost in the fall of the same year, it is estimated that the earth would be covered with flies to a depth of 47 feet. Obviously no organism realizes its geometric reproductive potential. The actual growth curves of populations can be plotted by observing the developments of populations of yeast or water fleas as they enlarge and stabilize in limited environments. Factors which limit population size such as food, crowding, and toxic wastes can be controlled in many experiments. The results of research on overpopulation are especially significant today since man's environment has become less limiting, and overpopulation is disturbing more groups than demographers.

For references, see C. Hardin. *Biology: Its Human Implications.* W. H. Freeman and Company, San Francisco, California. 1950.

G. C. Simpson, G. S. Pittendrigh, and L. H. Tiffany. *Life: An Introduction to Biology.* Harcourt, Brace and Company, New York. 1957.

Regeneration

All organisms are capable of regeneration. The degree of regeneration, however, appears to be quite variable in the animal kingdom. Man can regenerate or replace parts of lost tissue such as skin or bone, but a leg of a developed mammal cannot be replaced nor can the leg of a mammal give rise to the whole organism. Many phyla have amazing regenerative powers. Flat worms, starfish, hydra, and other simple organisms can be cut in two, and sometimes more pieces with each piece developing into a completely normal organism. Embryos of organisms have high regenerative abilities, or capacities.

1. Among the amphibians, salamanders can regenerate lost appendages. Frog tadpoles can regenerate lost appendages. Adult frogs cannot normally regenerate lost legs—scars grow over the stumps. Why is this so? If the scar tissue were prevented from forming by surgery or chemicals, would regeneration occur?

2. The eye of the crayfish is a modified appendage. Were it removed, would a leg or an eye grow back?

3. At what stage(s) of their life cycle can insects replace lost parts?

4. What is the smallest vegetative plant structure capable of regenerating an entire plant? (One botanist claimed to have been able to start a plant from a cutting of a *stamen filament!*)

Students work effectively as a team in standardizing solutions for research investigations.

NORTH HILLS HIGH SCHOOL, PITTSBURGH, PA.

Respiration

The rate at which oxygen is consumed by a small animal such as an insect or an earthworm can be measured by placing the animal in a jar where absorbent paper soaked in 0.4 per cent KOH is suspended. A one-hole stopper fitted into the jar holds a 0.2-ml pipette containing one drop of dye at its distal end. As oxygen is consumed and carbon dioxide is absorbed, the drop of dye moves toward the jar or the path down the pipette.

This jar respirometer lends itself well to experimentation where the temperature of the animal is being controlled since the jar can be placed in constant temperature baths. A considerable amount also can be done in varying humidity, pressure, and gas ratios in the environment of the animal. Such an apparatus enables one to pretreat an insect before testing it in the jar. For examples, does an insect consume large quantities of oxygen after heavy exercise, as mammals apparently do?

Sleep

What is sleep? What are the effects caused by lack of sleep? How do waking reaction times vary? Can you learn while asleep? What body functions change during sleep? Is the best sleeping position for everyone horizontal? What is the curve of depth of sleep versus time? Is there such a faculty as a mental alarm clock? Is anesthesia a sleeplike state?

Slime Molds

Maintaining a den of snakes or aquariums of fish are exciting hobbies which can stimulate some challenging research projects. One uncommon group of organisms to culture, observe, and experiment with are the slime molds. They can be collected in woodlands or purchased from the biological supply houses. (An excellent species is *Physparum polycephalum.*) The slime molds are the prototypes of that all-devouring, indestructible, flowing organism often featured in science fiction stories. Actually slime molds engulf everything they can. They can be punctured and torn apart. The plasmodium will repair the hole, and the torn pieces will often rejoin the body. For research purposes slime molds are excellent subjects for studies of protoplasmic streaming.

For references, see J. Alexopaulos. *Introductory Mycology.* John Wiley and Sons, Inc., New York. 1952.

W. Crowdin. "Marvels of Mycetozoa." *National Geographic,* 49: 421-43. April 1926.

Suspended Animation

Collect a jar of sediment from a dried-out pond or pool. Add sterile water to some of the sediment in an aquarium. Observe and identify the many forms of plants and animals that appear. Examine the dry sediment attempting to identify the forms in which specific organisms resisted drying out. Can the specific adaptation of each organism to adverse environmental conditions be discovered through an induced test? Are the adaptations of organisms to dessication comparable to their adaptations to other adverse conditions such as winter temperatures? How long a dry spell can mosquito eggs tolerate? Through how long a winter can a frog hibernate? What extremes of temperature, age, exposure to acids, bases, and salts, and deprivation of oxygen can seeds, spores, eggs, or cysts tolerate?

Symbiosis

The alimentary canals of man and other organisms are extensive botanical, and often zoological, gardens. The plants of the garden are mainly bacteria which function primarily to break down food and wastes. For almost every kind of organism there are worm parasites which are structurally and physiologically obligated to live with the host. These internal residents can be either beneficial or injurious in their relationships with the host organism.

1. How many different kinds of organisms can be identified in the intestines of fish, frogs, snakes, birds, dogs, or cockroaches?

2. By construction of a gas-tight pair of pants fitted with a valve, determine the volume of intestinal gases generated by the bacteria of the large intestine. What is the chemical composition of the expelled gases? What relationships exist between the kind of food ingested and the composition and volume of gas expelled? Which bacteria are responsible for this action? Can the process be duplicated outside of the body?

3. In the digestive system of cows, other ruminants, and termites, cellulose is hydrolyzed by microorganisms. Can this process be duplicated and controlled outside of the body of any of the organisms described?

4. Among other advantages, intestinal bacteria are said to produce vitamins essential to the host organism. Can mammals such as mice or rats, delivered by Caesarian birth and maintained in sterile isolation, live as long and be as healthy as controls that have been infested with microorganisms?

5. Do antibiotics kill off beneficial intestinal microorganisms, as a side effect?

Tranquilizers

Tranquilizers, or psychosedatives, are a class of drugs which have proven therapeutic value in the treatment of a range of disturbed mental conditions. Veterinarians are using tranquilizers to calm frustrated dogs and bring chickens to a higher level of egg productivity. The action of these drugs seems to block certain chemicals found in the body. The physiological side effects of tranquilizers, however, are often undesirable. There is further concern that people are using tranquilizers as escape mechanisms and are not doing anything about the real cause of their disorder.

1. Are bees which are fed tranquilizing drugs in honey less inclined to sting intruders than bees that have not been calmed?

2. To what degree are the activities of laboratory animals influenced by tranquilizing drugs? Activity may be measured by attaching a revolution counter to an exercise wheel or placing a circuit key beneath a suspended cage supported by a spring.

3. What are the effects of tranquilizers on maze learning in rats when:

   a. age groups vary?

   b. animals are learning under high tension?

   c. kinds of tranquilizers vary?

   d. concentration of tranquilizers vary?

4. Do tranquilizers affect the rate and the limit of growth of certain or all animals?

5. Do tranquilizers reduce the intensity of sex, thirst, or hunger drives?

6. Do all intravenously injected tranquilizers affect the heart cycle of a frog?

7. Can laboratory animals become dependent or addicted to depressants?

Visual Inversion

The image that falls on the retina of the eye is inverted. Apparently the brain turns this image over so that we perceive objects as being erect. It is said that if a person were to receive erect images on the retina, the brain would adjust to the change, and in time, these upside-down images would appear normal. With the assistance of an optometrist, a set of inverting glasses might be constructed which will enable an investigator to test this hypothesis.

Additional Questions in Biology

1. How accurate is a person's facial vision? "Facial vision" may be thought of as the ability to avoid walls and other obstructions at night or when blindfolded.

2. Does aspirin in water prolong the show-life of cut flowers? Can other substances be found to accomplish this?

3. Are there substances which produce antagonistic or synergistic effects on the action of certain antibiotics? Do combinations of chemical catalysts produce synergistic effects?

4. Should the stems of roses be cut back in the fall after frost, in the spring before the emergence of new growth, or never?

5. Seeds dispersed by ocean currents must be less dense than and resistant to the plasmolyzing effects of salt water. What are the special properties of seeds and fruit which are so adapted?

6. Why do popcorn and, to a lesser degree, other varieties of corn pop?

7. Pyrethrum is an insecticide powder extracted only from certain chrysanthemums. Do these flowers affect insects which contact them?

8. Is there such a physiological phenomenon as a "second breath"? To what extent is the "second breath" a psychological development?

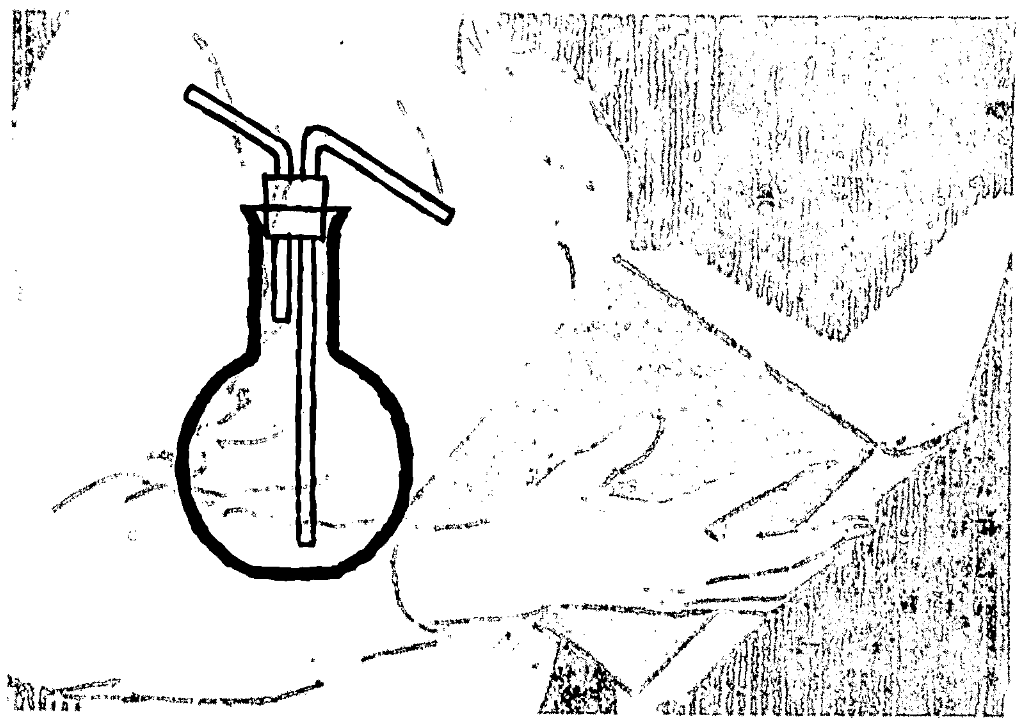
9. What are the relative efficiencies of surgeons' face masks in filtering germs from the wearer's breath?

10. What is the optimum sugar concentration in which pollen grains will germinate?

11. Do insects see colors?

12. How much pressure in pounds-per-square-inch or how much heat in BTU's is recorded when observing the germination of seeds? What happens?

VII. Chemistry



Air Pollution

As the population increases, cities become more crowded and civilizations become more mechanized. Clean air becomes more and more scarce. Automobile and truck engines alone pour about 20,000 tons of carbon monoxide into the atmosphere each day. In recent years, corrosive smog has ruined many pairs of nylons. Many people otherwise only mildly afflicted with pulmonary disorders have died as a result.

Natural processes of wind circulation and precipitation remove many undesirable substances, but these processes are limited. Many of the waste products discharged into the atmosphere are harmless until acted on by sunlight. The latter apparently promotes photochemical reactions that produce irritating effects.

1. What substances are found in rain which are the result of man's being on earth?
2. What is the ultimate fate of the carbon monoxide discharged into the atmosphere? Is it accumulating, or are there natural processes that remove it from the air?
3. Is carbon monoxide slowly oxidized to carbon dioxide by atmospheric oxygen?
4. Could some chemical reaction of carbon monoxide be utilized to remove the substance from automobile exhaust? (Approximately 7 per cent of automobile exhaust is carbon monoxide.)
5. What specific chemical reactions among exhaust products are initiated by sunlight?

Alkaloids

Quinine, nicotine, and strychnine belong to a group of chemical compounds known as alkaloids. Members of this group are among the most useful of medicinal substances, yet others are among the most deadly poisons. Curare, containing curine as the principal alkaloid, is the well-known poison used on tips of arrows in South America.

Many common plants contain an alkaloid. This is rather surprising when the general physiological action of alkaloids is considered.

1. What function of plants is facilitated by the presence of alkaloids?
2. What would be the physiological effect of injecting tobacco plants with nicotine?
3. In what specific part of a plant is a given alkaloid found?
4. Much publicity has been given to the nicotine content of smoking tobacco. Chemical processes can remove it. Can the nicotine content of tobacco be regulated by controlling the physical and/or chemical environment of plants?
5. Can undesirable alkaloids such as nicotine be neutralized without removing them from the plant? If removed, what happens?
6. Is the nicotine content of tobacco affected by the customary aging of tobacco leaves in drying sheds?
7. Does tobacco contain the same proportion of nicotine from seedling to mature plants?

Anodizing

Anodic oxidation (anodizing) has found some application commercially to produce a resistant coating of aluminum oxide on metallic aluminum. One process for producing colored aluminum, and yet retaining its metallic luster, depends on anodizing aluminum which is alloyed with other substances.

The process itself requires a source of direct current and a conducting bath, usually dilute sulfuric acid. The metal forming the anode becomes coated with an oxide when voltage is applied.

Other combinations of metal-to-metal oxide are interesting. For example, copper oxide in contact with pure copper exhibits a photovoltaic effect (*i.e.*, light produces electricity).

1. How is the physical nature of an aluminum oxide coating affected by varying the current density, temperature, and related elements of the bath?
2. Do all anions in solution result in the same oxidizing effect at the anode?
3. For metals like copper, iron, and nickel which exhibit variable oxidation numbers (valence), what determines which oxide is formed?
4. Can all metals be anodized?
5. Are physical effects other than the photovoltaic effect displayed by metal-to-metal oxide interfaces?

Calcium Carbonate

Calcium carbonate is a common compound in rocks of sediment origin. Limestone, marble, and chalk are largely $CaCO_3$, and shales and dolomites are often rich with this substance. Since ground water contains carbonic acid, (geologically speaking) the carbonate rocks are readily weathered by dissolution producing such formations as caves. While $CaCO_3$ is being removed from the land, it is being deposited in the ocean by many organisms which use the compound in building skeletons. In shallow warm seas, $CaCO_3$ sedimentation can be observed to occur in a manner similar to the formation of boiler scale or the deposit of travertine around the mouths of hot springs.

1. The crystals of $CaCO_3$ may occur in either of two forms, calcite or aragonite. Which is the more stable of the two forms? Which is the more soluble? Does this stability-solubility relationship hold true for other compounds that occur in more than one crystalline form?

2. Effervescence is a qualitative test in which acid is used to identify carbonate rock. If a gas is given off with the addition of acid, the substance tested is a carbonate. Under what conditions and to what extent can calcium carbonate be dissolved in acids? Do salts containing calcium ions, and salts not containing calcium ions, influence this solubility?

3. What is the nature of limestone weathering? With relation to the structure of limestone bed rock, where does a cave start forming? How does the weathering of air-exposed limestone differ from the weathering of limestone which is several feet below rich top soil?

4. The origin of fine-grained nonfossiliferous limestone is unknown for most localities. Are there any clues in the limestone of your area that would indicate whether the origin was chemical percipitation or finely ground shells?

5. At what rate do stalactites form?

6. Why does blackboard chalk generally break into three pieces when it is dropped? Why does it break in a spiral when twisted? Why does chalk often squeak when used on a blackboard? How does natural chalk compare with manufactured chalk in density, adhesion to slate, fossil content, and as to the porosity?

Students from Western Hills High School in Cincinnati tour a modern laboratory for direct observation of current research and to discuss questions with a working scientist.

WILLIAM S. MERRELL COMPANY, CINCINNATI, OHIO

Clock Reactions

The "iodine clock" and the "formaldehyde clock" reactions are often used in chemical magic shows. By mixing two colorless chemical solutions an unobservable chemical reaction is started. When one of the reactants is used up, a third substance, an indicator, suddenly produces a bright color (deep blue for the iodine clock, red for the formaldehyde clock).

More important than the spectacular color effect is the fact that these reactions offer excellent opportunities to study chemical reaction rates. The individual reactions begin when the solutions are mixed and can be considered complete when the color suddenly appears during the test.

An experiment using the iodine clock reaction is included among the *Scientific Experiments in Chemistry* available from the Holt, Rinehart, and Winston, Inc., of New York at reasonable cost. These experiments are directed toward discovering the effects of temperature and concentration on chemical reaction rates.

Other problems which might be attacked by using these reactions are:

1. Do different clock reactions show the same results when temperature and chemical concentrations are varied?

2. Are there positive and/or negative catalysts for these reactions?

3. Are chemical reaction rates affected by variations in gravity? (A centrifuge could be used to produce extra g's.)

4. What effect does ultrasonic vibration have on chemical reaction rates?

5. Are chemical reaction rates affected when the reaction is carried out in a strong magnetic field?

6. Does ionizing radiation affect chemical reaction rates?

7. Do chemical reaction rates proceed at the same rate when an electrical current passes through the reactants? (Both AC and DC current may be used for experimentation.)

Concrete

A ready-mix concrete truck broke down while making a delivery. The driver ran to a nearby supermarket, bought five pounds of sugar, ran back to the truck, and poured the sugar into the concrete.

When asked the reason for this peculiar action, he said it was to prevent the concrete from hardening. He did not know how long he would have to wait before the truck could be repaired, and what is more useless than a cement mixer full of hardened concrete? The driver did not know why the sugar acted as it did. He did know he was following the procedure recommended by his employer in case of a breakdown. He also knew the sugar treatment worked.

On another occasion a contractor was pouring a concrete floor in a new building. The walls and roof were in place, but since it was winter, fuel-oil burners were needed to heat the interior. After pouring the surface for the floor, the cement did not harden. The contractor thought it was due to the exhaust fumes from the heating units. Although not sure of the reason, he was sure that if the floor were dug up and repoured *without* the heaters going, the concrete would harden.

1. What substances prevent concrete from hardening?

2. Are there substances which will counteract the actions of sugar in concrete?

3. Why does sugar prevent concrete from hardening?

4. Are there substances which will increase the hardening rate of concrete?

5. How do changes in environment affect the rate at which concrete hardens?

6. How can concrete be colored or given other special properties?

Problems with Detergents

Modern detergents are generally superior to old-fashioned soaps for most cleaning jobs. The new products have created some new problems, however, not the least of which is the difficulty of getting rid of detergents in sewage. Foam from detergents has greatly decreased the efficiency of sewage treatment. Difficulties may arise in processing detergent-loaded water for irrigation or other purposes.

1. Are there microorganisms which will metabolize detergents, and therefore be a potential method of disposing of used detergents in sewage effluent?

2. How do detergents in water affect the growth of green plants, fungi, or algae? Is there a definite tolerance limit by these plants?

3. Can chemical treatment remove detergents from dilute solutions?

4. Are cheap chemicals available which reduce the foaming of detergent solutions?

Electroplating Alloy

The electroplating of a metal from a solution of its ions is an easily observed phenomenon. Copper plating requires only a solution of a copper salt, a suitable electrode, and a source of direct current for the experiment.

If more than one metallic ion (cation) is present in a solution, you might expect the deposition of several metallic elements at the same time. If this occurred, it might be possible to electroplate alloys directly on a base metal. Actually this has been done, but many variables can greatly affect the expected reaction.

In experimenting with electroplating phenomena, it is generally advisable to use a graphite cathode to minimize side reactions. Salts of such metals as nickel, copper, bismuth, cadmium, and silver are especially adaptable to these experiments.

1. Is there a minimum voltage at which electroplating will occur?

2. Does the negative ion (anion) affect the deposition of metallic elements at the cathode?

3. If two metallic elements can be plated simultaneously, can a mixture of three or four be deposited in the same manner?

4. If two metals are plated together, does the plate have the properties of an alloy or a simple mixture of elements?

Energetic Electrons

Interesting visual effects are noted when a high-voltage electric discharge is passed through a tube from which air is steadily removed by a vacuum pump. The tube must be strong enough to withstand the pressure difference, and observations must be made in a darkened room. The effects are most pronounced when the applied voltage is DC current. The appearance of alternate bright and dark regions requires some detailed explanation.

The same tube and discharge could be used to study chemical effects. If the electrodes are iron, only one of them is observed to corrode rapidly. Other chemical effects might be noted by replacing air with various mixtures of gases. This has been done with mixtures of methane, ammonia, and hydrogen. After the electrical discharge had been continued for some time, amino acids were found to be present. One hypothesis to account for the origin of life on earth has been based on this phenomenon.

Certain crystalline substances subjected to an electric discharge show fluorescence while others undergo a permanent change in color.

(CAUTION: X Rays may be generated whenever high voltage electrons strike a target.)

1. Specifically, what amino acids can be produced by electric discharge? **(CAUTION: Avoid explosive mixtures of gases.)**

2. Do the various visible effects occur at certain pressures? If so, why?

3. Since the electric discharge is a stream of energetic electrons, what chemical changes could be expected to occur in crystals?

4. What energies must the electrons acquire before chemical changes occur in crystals? Is the air pressure critical?

5. Can the bombarding electrons be directed by a magnetic field to hit the target crystals more effectively?

6. How are the organic compounds affected by bombardment with energetic electrons?

7. Is the optical activity of certain compounds affected by bombardment with energetic electrons?

Engine Fuel

Is there one superior fuel for a two-cycle internal combustion engine? One aspect of this can be investigated by measuring the torque developed by the test engine using a dynamometer. Fuels that might be tested include regular gasoline, high octane gasoline, white gas, ethanol, benzene, and various mixtures.

Fission Products

Radioactive fission products from nuclear bomb tests have been scattered over the whole earth. These materials will be radioactive for many years. It is known that a common species of alga, *spirogyra,* may absorb seven times as much of certain radioactive fission products as does the alga, *euglena.*

Do common weeds absorb certain radioactive fission products at different rates?

Fizz

Many soft-drink companies have attempted to produce a product which retains its carbonation after the bottle is opened. Some have claimed that trademark processes such as "pin-point carbonation" keep the beverage from going flat.

Some soft drinks have a reputation for being more highly carbonated than others. No generally accepted method is available for testing the degree or permanence of carbonation.

Permanence of carbonation might be estimated quantitatively by measuring the volume of carbon dioxide released at a standard temperature and pressure as compared to the total volume capable of being released. Such comparison should be made for a fixed volume of beverage.

1. Is there a difference between the degree of carbonation of various soft drinks?

2. After being opened, do certain soft drinks retain their fizz longer than others?

3. Since the carbon dioxide bubbles in a soft drink result from the chemical decomposition of carbonic acid, is there a negative catalyst to slow the reaction? To be useful the substance obviously could not be toxic.

Freezing-Point Depression

The freezing point of liquids is lowered when substances are dissolved in them. One mole of sugar dissolved in one liter of water produces a solution which freezes at −1.86° C. A sodium chloride solution of the same mole concentration freezes at −3.42° C. The difference is explained by the dissociation of sodium chloride. In other examples, the solute produces a freezing-point depression quite different from that predicted by the Arrhenius Theory of electrolytic dissociation.

1. What solutes produce abnormal depression of the freezing point?

2. Do solutes produce the same depression for different solvents?

3. Why do solutes depress the freezing point of solutions?

4. What effect, if any, do suspended or colloidal substances have on the freezing point of liquids?

5. Do melting points of frozen solutions correspond with the freezing points?

6. Can molecular weights be determined by this technique?

7. Why does salt on ice produce a lower temperature than that of the original ice?

Heavy Water

Heavy water, deuterium oxide, is more readily available today than it was several years ago, but it is still expensive (50 grams cost $30). With proper care, use on a small scale, and systematic recovery, the cost of experimentation, however, it not prohibitive. For the high school scientist, the chief value of deuterium oxide is that it offers an unusual focal point for research.

Apparently the only difference between water and deuterium oxide is that the oxide, with the same formula, H_2O, has a hydrogen atom with atomic weight two, instead of the one. Structurally the two molecules are alike according to the accepted model. Some research has shown that seeds moistened with heavy water do not germinate normally.

1. Are the pH's of acids dissolved in deuterium oxide different from those dissolved in water? If so, why are there differences?

2. Does the electrical conductivity of heavy-water solutions differ from those of normal water? If so, why is there a difference?

3. How does the presence of deuterium oxide affect the life processes of microorganisms?

4. Does heavy water form crystalline hydrates the same as "normal" water?

Insecticides and Repellants

Many chemicals reportedly are effective in killing or repelling economically injurious insects. Pure strains of fruit flies introduced into cages which are lined with cardboard panels covered with Saran Wrap and previously sprayed with DDT or pyrethrum show variation in reaction. Where the "knock down" is fast, the killing power may be weak. The residual effectiveness of some insecticides may be greatly reduced by time, sunlight, humidity, or temperature.

Certain strains of insects have

greater resistance to an insecticide than other strains of insects, for example, fruit flies.

Where it is not practical to kill or trap insect pests, repellent measures are often taken. Certain frequencies of light and specific chemicals repel insects. What is their comparative effectiveness?

Chemicals and light can both attract and repel insects. Some insects attract each other by sound. Is it possible to repel insects with sound or certain vibrations?

Lubricants

Modern industry's machinery would soon slow and probably stop if the supply of lubricating oils became depleted. Every moving piece of machinery from automobile engines to wrist watches requires proper lubrication.

Recent commercial developments feature motor oils which maintain a given viscosity over a wide temperature range and automobiles that may go 4000 miles between oil changes.

1. Can old oil drained from automobile crankcases be reprocessed for use, or is it really worn out?
2. Does the phenomenon of thixotropy have importance in the all-temperature oil?
3. How are the lubricating properties of oils affected by high pressures? Is the same effect noted for solid lubricants such as graphite and lead oxide?
4. Do lubricants vary in effectiveness if the part to be lubricated is magnetic?
5. Does water, or any other substance, cause a noticeable decrease in the action of a lubricant?
6. Is the effectiveness of a lubricant a function of molecular size, or molecular weight, or of molecular geometry?

Metal Toxicity

The copper ion is known to be toxic to certain microorganisms. A penny in an aquarium is said to prevent the growth of algae, and copper sulfate when introduced into ponds kill fouling protoza. During World War II, an experimental treatment for fungus infections of the feet was to electroplate copper on the infected foot. Lead and mercury are metals known to be dangerous poisons.

1. To what extent does metallic copper embedded in agar retard the growth of pure cultures of mold?
2. What other heavy metal elements inhibit mold growth? To what degree?
3. Does a mouse whose tail is immersed in an attached tube of mercury evidence any response to the metal absorbed through the skin or other parts?
4. Are heavy metallic ions absorbed by land plants? Is soil containing arsenic fatal to these particular plants?

Study of pH

Several methods may be used for direct measurement of the pH of a solution. Among these are colorimetric indicators and electronic pH meters. Textbooks of general and analytical chemistry are good references in calculating the pH of laboratory and natural solutions. Many quantative projects can develop from various pH investigations.

1. How closely do the calculated pH values agree with the measured value?
2. Do different techniques of measuring pH result in different values?
3. How do pH reactions of patent medicines agree with advertised claims?
4. How does the acid or alkali content of vinegar, lye, soaps, and other household chemicals agree with the labels?
5. How much does the concentration of a given solute affect the pH of the solution?

Ozone

A large portion of the ultraviolet (UV) radiation coming from the sun is removed by the upper atmosphere. Without this filtering action, the intensity of ultraviolet radiation would make life on the earth's surface, as we know it, very difficult or even impossible.

The mechanism by which ultraviolet energy is absorbed involves the transformation of molecular oxygen (O_2) to ozone (O_3). Ozone

Establishing suitable working quarters for students working on a project is a basic necessity. In this view, two students who could not have a home laboratory in which to work were assisted by their teacher who set up a working laboratory in a garage that was not being used.

LAKEWOOD HIGH SCHOOL, LAKEWOOD, CALIF.

contains more energy than ordinary oxygen and is generally more reactive. Traces of ozone, distributed by the natural circulation of air, are found throughout the atmosphere. Probably the chief cause of the hairline cracks that appear in the sidewalls of automobile tires is the reaction of ozone with rubber.

Ozone is formed by electrical discharges especially of the "glow" or quiet type. The peculiar odor associated with television sets and other electronic apparatus is due to ozone. Ozone has been used to kill bacteria in water, and some attempts have been made to kill bacteria in air by using small ozone-generating UV lamps.

1. How effective is ozone in killing air-borne bacteria?

2. Since ozone is irritating to humans, possibly lethal in high concentration, what is the minimum concentration of ozone in air that can be detected by smell?

3. Ozone will liberate free iodine from potassium iodide at room temperature, but ordinary oxygen will not. Can this fact be utilized to devise quantitative test for the concentration of ozone in the atmosphere? If so, does the ozone concentration of air vary from day to day? Ozone has been suspected of contributing to the formation of irritating smog.

4. Since O_3 is unstable and ultimately changes into O_2, what is the half life of ozone under various conditions?

5. Could ozone be added to the air intake of a gasoline engine to improve performance?

6. What is the most efficient method of generating ozone? Can a catalyst be found to be used with either ultraviolet or electrical energy?

Study of Potassium 40

Potassium 40 (K 40) is an unusual isotope of a relatively common element. Potassium ranks among the most abundant elements of the earth's crust. Being quite active chemically, it is found only in compounds. Rocks, plants, and animals contain these compounds. The ash of woody plants contains a fairly high percentage of potassium compounds.

Most potassium compounds are soluble, and ocean water contains a considerable amount in solution.

The most common potassium atoms (K 39 and K 41) comprise over 99 per cent of all potassium. Natural potassium contains a trace of K 40 about 0.1 per cent. K 40 is radioactive and has a half life of approximately 10^9 years. For such a long half-life isotope, it produces an unusually energetic beta particle (1.4 mev) and therefore is detectable by ordinary Geiger counters available.

Although potassium apparently is necessary to all plants, its role in plant physiology is not completely understood. A scaler would probably be needed in experiments utilizing K 40 since the level of radioactivity would be low.

1. How does the K-40 content of new wood compare to old wood? An opportunity to obtain different ore samples from a cross section of an old tree would be a good starting point. The wood must first be ashed. What is the significance of any substantial difference?

2. Does the K-40 content vary with source and geologic age? If differences are noted, what conclusions might follow?

3. What plant tissues contain the most potassium? This might give a clue to potassium's function in plants.

Precipitation of Ions

When two solutions of different solutes are mixed, an insoluble precipitate may form depending on the nature of the original solutes. This type of chemical reaction is often used either to prepare certain insoluble compounds or to remove a specific ion from one of the original solutions. Precipitation reactions are especially useful in analytic chemistry.

1. Can a given ion be removed completely from a solution by reactions producing precipitates? The use of radioactive tracers would seem to offer a way to answer the question.

2. How can certain potentially dangerous fission products such as Strontium 90 best be removed from water?

3. Can you make a quantitative recovery of the precipitate? How does the actual result agree with the theoretical result?

Saliva

Think about lemons! The chances are that when you do, you will notice an increased flow of saliva in your mouth. On an average, a man secretes about 1500 ml of saliva in twenty-four hours. Like most statistics about the average man, this one is subject to wide variation. Saliva is known to be a contributor to digestion of foods. It is also an important factor in maintaining the health of the teeth and tissues of the mouth.

1. How do individuals vary in the amount of saliva secreted?

2. Is tooth decay related to some special characteristic of the individual's saliva?

3. Does a diet of carbohydrates (sugar and starch) alone change the composition of the saliva?

4. What specific foods are digested by components of saliva?

5. Is saliva more or less effective when diluted with water?

6. What stimulates and/or slows the flow of saliva?

For reference, see *Dental Projects for High School Science Students*. American Dental Association. 1959. (Available from Science Service, Inc., Washington, D. C.) (Single copy, 25 cents.)

Sawdust to Sugar

Prior to World War I, German chemists searching for new sources of food discovered that wood can be converted to sugar by chemical reaction. While the carbohydrates such as sugar are not scarce in this country at present, future generations probably will be faced with a food problem.

In many parts of the world today protein foods are scarce. Recently certain varieties of fungi have been shown to be efficient in chemically converting some carbohydrates to proteins. Biochemistry may hold the key to the future nutrition of the world.

In addition to food, sugar can be the chemical forerunner of alcohols, aldehydes, and other materials of these kinds.

1. What chemical processes will convert wood to sugar?

2. What physical conditions will produce a maximum yield of sugar from wood?

3. Can a catalyst be found for the conversion reaction?

4. Does it make a difference if the wood is in the form of chips, shavings, or sawdust?

Synthetic Rubber

A type of synthetic rubber known as a polysulfide polymer can easily be made in the laboratory. The process does not require high pressures or temperatures. The only reactants are a saturated solution of sulfur in 4 per cent sodium hydroxide solution and 1,2-dichlorethane (ethylene dichloride).

The polymer is formed by placing the two immiscible liquids in contact with each other at a temperature near 60° C. The product of the reaction is a light yellow rubbery substance. When washed free of excess sodium hydroxide, it is safe to handle the synthetic rubber without any effect.

This polysulfide polymer has two shortcomings. First, it has a very strong disagreeable odor. Second, it slowly loses its rubbery character over a period of time.

1. What improvements in the final product could be made by carrying out the polymerization in varying conditions such as high temperature, ultrasonic vibration, violent agitation, etc?

2. Can the final product be changed by using different reactants (e.g., 1,2-dibromoethane in place of 1,2-dichloroethane)?

3. What effect on the final product could be brought about by adding a substance such as a salt to the reaction mixture?

4. Could a plasticizer be worked into the polymer by mechanical means after it has been washed? The desired effect would be to prolong the rubbery life of the substance. Almost any substance could be used as the plasticizer.

Additional Questions in Chemistry

1. What change, if any, is observable in the chemical make up of rain?

FAIR LAWN HIGH SCHOOL, FAIR LAWN, N.J.

Two students work together at a local scientific laboratory as part of their science-work program.

2. Can synthetic stalagmites be formed in the laboratory?

3. Does magnetized iron have a different chemical reaction than unmagnetized iron?

4. Can some ionic compounds be crystallized with alcohol of crystallization in place of water crystallization?

5. To what extent does the natural acidity of woods increase the corrosion of iron fittings under damp conditions?

6. Is weathering of concrete or asphalt pavement accelerated by the use of salt to remove ice? If so, how can this effect be minimized generally?

7. What are the chemical products of the methanol-hydrogen peroxide fuel cell? (A demonstration unit is available at moderate cost from the Allis-Chalmers Company, Milwaukee, Wisconsin.)

8. Can alloys be made of a metal and a compound, e.g., lead and lead oxide?

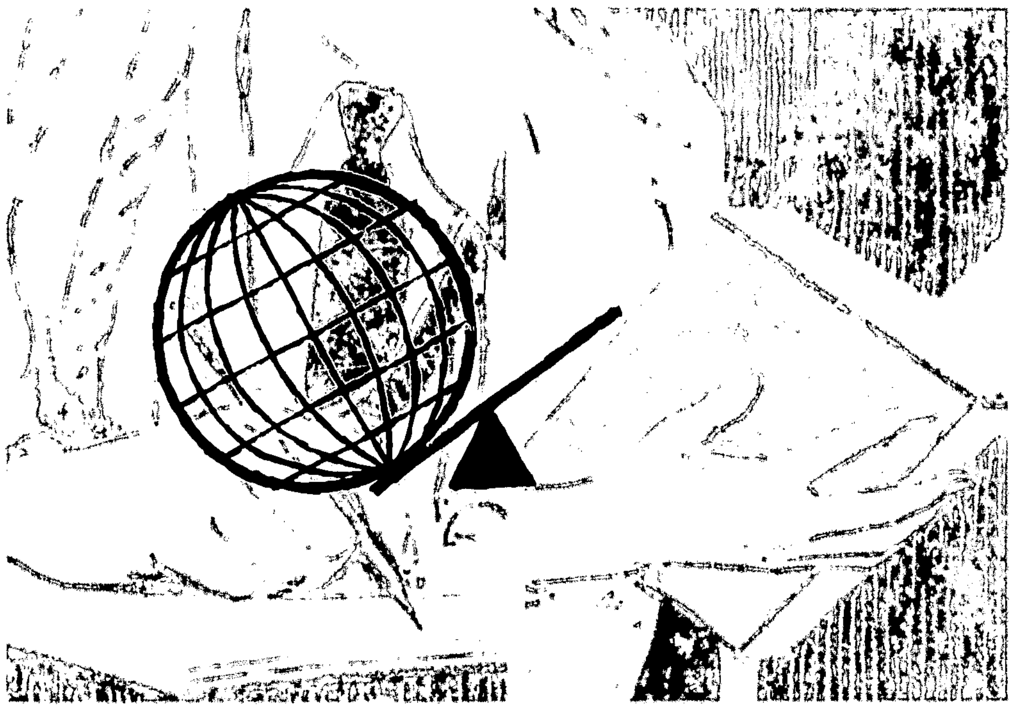
9. Can mixtures of ions be analyzed by radial diffusion in plates of gels where resulting concentric rings are developed with certain color indicators?

10. What volume and kind of gas is cocoanut charcoal capable of absorbing?

11. Why does the odor of coffee differ from the taste of coffee?

12. Why does frost form on windows in leaf or fan shapes, swirls or crystals?

VIII. Physics



Barkhausen Effect

One end of a long iron rod is inserted as a core into a current-conducting coil. As the direct current is increased steadily, the magnetism of the rod is observed to increase in finite jumps (Barkhausen Effect).

1. What result does temperature have on the effect?
2. Would a glass tube packed with iron filings show the effect?
3. Does the steady decrease of the energizing current result in a similar decrease in magnetism?

Boomerangs

A properly shaped piece of wood, thrown in a certain manner, will return to the thrower. The device, of course, is a boomerang. Though boomerangs are most familiar to us as toys, many primitive cultures used them for hunting and also as war weapons.

Primitive men probably did not understand why the boomerang behaved as it did. In fact, no completely satisfactory theory of operation has ever been published.

1. What boomerang shapes are possible?
2. Why are left-handed boomerangs unknown?
3. What theory can you develop to account for the unique action of the boomerang? This might best be developed by experimentally investigating the variable properties of boomerangs such as center of mass, cross sections of the arms, angle between arms, surface-to-weight ratio, and similar factors to be found.

Bouncing Balls

A bouncing ball is one of the most common sights in our society. The size, shape, constituent materials, density, and weight of balls vary considerably. The physics of a bouncing ball includes the interplay between kinetic and potential energy, the transformation of energy, and the elasticities of the ball and the reflecting surface.

1. Can the deformation of the ball and the reflecting surface be measured?
2. Can the rise of temperature of the ball and the reflecting surface be measured?
3. How is the resilience of an air-filled ball altered when the gas is replaced with CO_2 or He?
4. Describe the loss of potential energy from the peak of a bounce until the ball finally comes to rest.
5. Is there a mathematical relationship among steel balls bouncing on solid steel surfaces, rubber balls bouncing on solid rubber surfaces, and oak balls bouncing on solid oak surfaces?

Brewster's Law

The glaring reflection of light from roads is generally polarized horizontal to the road's surface. Vertically polarized sun glasses are useful in reducing this glare to some extent.

Brewster's Law states that for some angle of reflection from a surface, a maximum of polarized light is available. Reflected light from a series of thin glass plates may be as much as fifty per cent polarized.

1. Is the angle producing a maximum of polarization the same for different wave lengths of light?
2. Does submerging the reflecting surface in water or some other fluid affect the degree of polarization of the reflected light?

Composite Motion

•

If you are the steady type, the above dot is motionless with reference to you. If you are in a car, the dot has a magnitude and direction of motion with reference to the ground. If the car is bouncing and swaying, two more vectors may be added. The earth, the solar system, the galaxy, the local group, and the universe are in motion. With reference to a fixed point in space, what are all the component motions of the above dot?

Dielectrics

Capacitors are used in most electronic devices such as television and radar. The electronic equipment in spacecraft may be subjected to environmental conditions quite different from those on earth. It is very important to be certain that the equipment will function properly before using it.

A capacitor is a device for storing electric charge. In its simplest form it consists of two metal plates separated by air. The maximum charge that can be stored in the

CARL PURCELL, NEA

All quantitative projects involve the use of mathematics as a tool.

capacitor depends on the area of the plates, the distance between the plates, and the nature of the substance dielectric separating them. The dielectric constant of each substance may vary as environmental conditions change.

1. How is the dielectric constant of various materials affected by extreme temperatures, severe vibration, weightlessness, or high levels of radiation?
2. Why are some substances good dielectrics and others not?
3. When two liquid dielectrics are mixed, how does the dielectric constant of the final solution compare to the pure liquids?

Earth's Magnetic Field

At Columbus, Ohio, the earth's magnetic field is strong enough that if a single wire loop enclosing an area of one m^2 were rotated at 3600 rpm, it could generate a peak voltage of the order of 0.01 volts. If the rotating coil has 100 loops, nearly one volt could be produced. These relationships might be used to measure daily or hourly variations in the earth's magnetic field.

Another relatively simple method of determining the direction and magnitude of the earth's magnetic field utilizes a Helmholtz coil, a magnetic compass, an ammeter, and a variable source of current.

1. Are there daily variations in the earth's magnetic field?
2. Are there hourly variations in the magnetic field of the earth?
3. Are variations in the earth's magnetic field related to buildings, large bodies of water, mountains, and similar variables?
4. (a) Does weather affect the earth's magnetic field? (b) Do the variations, if there are any, in the earth's magnetic field affect the weather?
5. Does the relative position of the moon affect the local magnetic field?

Electrolyte Resistance

Ohm's Law does not hold true for electrolytic solutions. The apparent resistance of a solution conductor is affected by voltage (Wien effect) and by the frequency of the applied voltage (Debye frequency effect).

1. Can Ohm's Law be modified to describe the voltage, current, and resistance relationships of conducting solutions,
2. Does temperature, agitation, or ultrasonic vibration have an effect on the conductance of an electrolytic solution? If so, could measuring devices for these forms of energy be invented?

Electro-osmosis

Water is known to move through a porus material toward the cathode (negative electrode) when electrical voltage is applied to electrodes in the porus material. This phenomenon is known as electro-osmosis.

This effect has been used to stiffen wet earth while excavations have been made.

1. Will the effect work with very pure water?
2. Will other liquids show the same effect?
3. What voltage is necessary to produce the effect?
4. Would the effect be practical to stiffen muddy football fields?

Fallout

Fallout is an often-heard term that usually implies radioactivity. Fallout, however, occurred on earth long before man made his appearance, and not all fallout is radioactive. Any dust which settles from the atmosphere can be termed fallout.

Although we usually regard dust in the air as undesirable, several experiments have shown that rain requires small dust particles around which droplets can form. Numerous sources of dust are known, including wind, volcanoes, meteors, and atomic bombs.

1. Can microscopic or other tests identify certain particles of air-borne dust as meteoritic? If so, what proportion of the total dust is meteoritic?
2. How effective are conventional air filters in removing radioactive dust? Is radioactive fallout confined to a certain range of particle sizes?
3. Do long half-life fission products have a characteristic particle size?
4. How effective is rain in removing dust from the troposphere?
5. Is all air-borne dust effective in providing condensation nuclei for rain?
6. The famous Krakatoa eruption produced persistent dust and caused halos to form around the sun. These halos were about 23 degrees in radius and 10 to 12 degrees wide. Could this optical effect be used in the laboratory to determine the size of dust particles?
7. How effective is the human nose as a dust filter?
8. When dust is inhaled by mammals, what is the ultimate mode of disposal from the organism?
9. The proportion of ultraviolet light in the radiant energy received at different parts of the earth varies considerably. Is air-borne dust the controlling factor?

Gauss Effect

Bismuth metal varies greatly in electrical resistance when it is in a magnetic field. This effect, known as the Gauss effect, is shown by many metals. The direction of the magnetic field also influences the resistance.

1. Could this effect be utilized in making a magnetic-field-strength gauge?

2. Which metals exhibit the greatest and/or the smallest Gauss effect?

3. Do electrolytic solutions show a Gauss effect?

4. What model of the structure of metals could account for the Gauss effect?

5. Why does the Gauss effect occur?

6. Do other parameters influence the magnitude of the Gauss effect (e.g., temperature or vibration)?

7. Is a gaseous conductor (a low-pressure neon tube) subject to the Gauss effect?

Greenhouse Effect

The mean temperature of the earth's atmosphere may be increasing. Evidence cited for this is the shrinking polar ice caps. Scientists have estimated that a five-degree increase in the mean temperature would melt enough ice to raise the ocean levels more than 100 feet, thereby threatening many of the world's cities with flooding.

One hypothesis to account for the warming trend is an increase in the carbon dioxide content of the earth's atmosphere. Carbon dioxide permits passage of the short-wave radiant energy incident from the sun, but blocks the longer waves of the energy reradiated from the earth.

1. Are there other substances that show the same selective transmission of radiant energy? (Consider water vapor, ammonia, alcohol, etc.)

2. A general principle states that reradiated energy always has a wave length longer than the incident radiation. Is the shift of wave length predictable?

3. Why does carbon dioxide transmit certain wave lengths and not others? Is the filtering action a function of molecular weight? Of chemical composition?

4. Does the carbon dioxide content of the atmosphere vary from place to place and/or from time to time?

5. Do green plants have a maximum rate at which they can utilize carbon dioxide, or does the rate depend on the carbon dioxide content of the air?

6. Do all plants take up carbon dioxide at the same rate when leaf areas are equal?

Homerun Physics

Every spring many words are spoken about baseballs being more lively, thus permitting more homeruns to be hit in the major leagues. Another hypothesis to account for the increased homerun production is based on the belief that it is easier to hit a fast ball over the fence than it is a slow ball. "Junk" pitchers give up very few homeruns. A third hypothesis credits thinner handled bats with the responsibility for more homeruns.

1. How uniform are the physical characteristics of baseballs?

2. Does temperature affect the properties of a baseball?

3. Is it easier to hit a fast ball for a homerun?

4. Does the type of bat affect the homerun hitting?

Kerr Effect

When subjected to a high voltage, certain liquids transmit incident plane polarized light as elliptically polarized light. This effect ceases when the applied voltage is removed.

Commonly known as the Kerr effect, this phenomenon has been utilized in a photographic shutter capable of opening and closing in 5×10^{-9} seconds.

1. Why don't all substances exhibit the Kerr effect?

2. What result does temperature variation have on the effect?

3. Does a magnetic field influence the effect? Does ultrasonic vibration influence it?

Lichtenberg Effect

A dielectric (plastic or hard rubber) in the form of a plate is touched at different spots with oppositely charged rods. This produces areas of different charge on the same plate. If a mixture of powdered red lead oxide and sulfur (flowers) is shaken and then sprinkled on the plate, the lead oxide adheres to the spots touched by the negative rod, while the sulfur adheres to the other areas. This is sometimes referred to as the Lichtenberg effect.

1. Why are the two materials attracted to the specific areas?

2. If magnesium or copper oxides were used in place of lead oxide, would similar results occur? What about other combinations?

3. Can a practical application be made of this phenomenon?

Magnets

Permanent magnets and electromagnets are common objects in the high school science laboratory. As far as we know the human senses are unable to detect a magnetic field. Yet magnetic fields are common, for example the familiar bar or horseshoe magnet, the field enveloping an electrical current, and the magnetic field of the earth, to name a few.

A primitive tribe in Africa believes that wearing a magnet on a necklace will insure the good health of the wearer. Most of us agree that magnets contain little magic. A note of mystery remains, however, about magnets and the forces surrounding them.

1. Can animals detect a magnetic field? If iron filings are placed in the aquarium environment of a crayfish, the animal's sense of balance will be disturbed by the magnetic effects. The effect is noted after the crayfish molts. Explain.

2. Is the growth of plants affected by a magnetic field?

3. Does the presence of a magnetic field affect the formation of crystals?

4. Are chemical reaction rates affected by magnetism?

5. Is the attraction between magnets affected by the substance between them (the substance could be air, water, glass, etc.)?

6. What is the most powerful magnet that can be constructed?

Mechanical Waves

Mechanical energy may be transmitted through a medium without transporting matter by means of waves. Gases and liquids (fluids) are able to transmit longitudinal waves, while solids are capable of sustaining longitudinal and transverse waves. Mechanical waves are most familiar as sound.

1. The speed of sound in a metal varies directly as the square root of the elasticity and inversely as the square root of the density.
   a. How can the speed of sound in small alloy metal rods be determined and checked?
   b. Does the above relationship apply also to gases? To liquids?

2. We know sound can be reflected. Can it be refracted? Can sound lenses be constructed to focus mechanical energy?

3. Is it possible for a sound to be destroyed by interference?

4. The crack of a whip is said to be a sonic boom. Can this be verified?

5. The olfactory sense cells in the nose and the touch receptors of the skin become fatigued after constant stimulation. Do the receptors for certain sound frequencies also fatigue?

Polarized Light-Magnetic Field

When a magnetic field is applied to a transparent material through which plane-polarized light is passed, the plane of polarization will rotate.

The magnitude of the effect is small. Approximately 50 cm of water in a field of 100 gauss would be expected to give a rotation of about one degree. A rotation of about two degrees would be produced with 100 cm of water.

1. How do other liquids behave?

2. Would solutions behave differently?

3. If an electric current were passed through an electrolytic solution, would the extent of rotation be affected?

Refraction Phenomena

When looking down into a glass of water, a dry object such as a piece of paper or a finger pressed to the outside of the glass cannot be seen. When the object is wet and pressed to the side of the glass, however, it can be seen. Accounting for this refraction phenomenon analytically and/or graphically can lead to problem projects such as illusional flying saucers and mirages. *The Nature of Light and Colour in the Open Air* by Minnaert answers and raises additional questions about refraction and other properties of light.

Sailboats

Sailboats are no longer valuable to the merchant marine fleets of modern nations, yet more are probably found in the United States now than at any previous time. The sea coasts and inland lakes offer unlimited opportunities for small sailboats to utilize the natural force of the wind.

Most skippers of small sailboats sooner or later become interested in racing. Many of the shorter races are decided literally by tenths-of-a-second. Sailboat-racing enthusiasts are constantly looking for ways to improve the speed of their boat. (Major modifications, like using larger sails, are forbidden in class races.)

1. Why do sailboats move? Some say the pressure of the wind pushing against the sail is the principal force. Others use an aerodynamic explanation in which the curved sail acts like an airplane wing.

2. What finish is best for racing hulls? It may seem that the smoother the finish is the less friction results, however, two highly polished steel blocks are very difficult to slide over one another.

3. Boats that stay in the water for a summer are apt to gather large quantities of aquatic organisms on their underside. What kind of paint is best to minimize this growth?

4. Even on moderately windy days, the upper deck of a sailboat may become wet with spray. When this happens, footings do become treacherous. Some oldtimers say that going barefooted is the best way to avoid slipping and falling overboard. Could a completely nonskid paint be developed?

5. Are there better devices than sails for utilizing the wind as propulsive power for a boat? (A ship equipped with Flettner rotors has been successfully tried.)

6. What are the vector forces acting on a sailboat?

Single Electrode Plating

A student in a class studying electroplating asked if copper would plateout from a solution of copper sufate if only a negative electrode were placed in the solution. It was tried and no copper was observed even when a high voltage was applied. Another student suggested that only a very small (*i.e.*, invisible) amount of copper was deposited since positive copper ions should be attracted to a negative electrode.

A more precise test was devised. A nickel sulfate solution was made containing several microcuries of radioactive nickel (no radiocopper was available). A graphite electrode was immersed in the solution, and a high negative voltage applied for five minutes. The electrode was removed, dried, and tested with a Geiger counter. The rod was slightly radioactive. A control test was run using identical conditions, *except that no voltage* was applied to the electrode.

The control showed *more* radioactivity.

1. Is the observed effect generally true?

2. If the same effect is reproducible, why does the observed result occur?

Static Electricity

Probably the first and one of the most common actions that produce electrical voltages is the rubbing of one substance against another. So-called static electricity is produced when a plastic rod is rubbed with a wool cloth. When this is done, the charge on the plastic rod is designated negative and the charge on the cloth, positive.

Two different metals at the same temperature produce a potential difference when rubbed together. The voltage is less than the plastic-wool pair. The friction of metal on metal explains the buildup of charge on automobiles in motion.

1. Can a series, corresponding to the electromotive force series, be established to predict the relative charges on nonmetallic substances when rubbed together?

2. Can a device be invented which will eliminate the shock received after sliding across plastic car seat covers and touching a door handle?

3. What pair of metals develops the highest potential difference when rubbed together?

4. Can the electromotive force series be used to predict voltages generated by rubbing two metals together?

Time and Clocks

Time is a unique phenomenon. A definition of time is very difficult to write although we all experience its passage. It is easier to measure time; all we need is a process or event which repeats itself regularly. By definition a precise clock is unvarying in its periodic motion.

The standard unit for this motion is 1/86,400 part of a mean solar day. The mean solar day is based on the apparent motions of a ficticious mean sun. Since the actual solar day is not constant throughout the year more dependable standard sources of periodic motion must be used, including crystals, molecules, and atoms. The search continues for the most reliable sources of periodic motion.

1. What is the greatest accuracy that can be obtained from such timekeepers as hour glasses, drip cans, burning candles, and chemical, mechanical, electrical, atomic, and piezoelectric clocks?

2. How do various makes of mechanical wrist watches vary within the normal extremes of temperature? Does a wrist watch subjected to the greater centrifugal effects at the equator maintain the same accuracy as it would at the North Pole where the centrifugal effect is slight?

3. The accuracy of the ordinary electric clock depends on the constancy of AC frequency maintained by local power stations. How constant is the AC frequency maintained in your community?

4. How many different clocks, each registering a different time, but each fairly accurate for one standard of reference, can you construct for your laboratory?

5. According to the theory of relativity, if two identical clocks A and B are synchronized, and then A is accelerated and brought back for comparison, A will record a shorter time interval than what is shown by clock B.

6. With what accuracy can the human mind judge intervals of time? Is it true that persons confined in darkness cannot distinguish minutes from hours, or hours from days after a period of time?

Unilateral Electroplating

A thin piece of metal, such as brass, when electroplated with

The high school laboratory contributes to actual work experience through the use of techniques and equipment used by the scientist in research.

ALAMO HEIGHTS HIGH SCHOOL, SAN ANTONIO, TEX.

nickel on one side only will bend away from the nickel plating. The stresses that cause this bending are present when a test strip is plated on both sides but oppose each other, and no bending occurs. These internal stresses are very troublesome in commercial electroplating because the plating tends to crack and peel away from the base metal.

1. How does the electroplating voltage affect the internal stresses in the plated layer?

2. Are the internal stresses dependent on plated metal, base metal, temperature of plating bath, or other variable conditions?

3. Can substances be added to the plating bath which will increase or decrease the stresses in the final product?

4. Can practical application be made of this phenomenon?

Vapor Pressure

The vapor pressure for most substances is not immediately apparent. If a careless Boy Scout heats a can of beans without puncturing the lid, however, a violent explosion will certainly convince him that vapor pressure is a very real force. The rapid evaporation of gasoline and the characteristic odor of some plastics is further evidence that molecules escape from liquids and solids. This tendency to escape is a crude definition of vapor pressure.

Many relatively simple instruments can be made to measure vapor pressure and form the basis for vapor-pressure studies. (See C. O. Colgate, and R. D. Whealy. *Journal of Chemical Education*, 32:484-5. 1955.)

1. How is the vapor pressure of a liquid affected by solutes? Do polar and nonpolar solutes produce the same effect?

2. How does the vapor pressure of a super cooled liquid compare with the solid state? (Water and solutions of sodium thiosulfate are easily supercooled.)

3. Are there regular relationships among vapor pressure, heat of fusion, heat of vaporization, molecular weight, viscosity, surface tension, and other similar properties?

Variable Friction

Whenever one object slides across another, the force of friction tends to retard the sliding. Edison found that when electricity flows between a metal strip and a piece of paper soaked in salt water, a decrease in friction between the two results.

1. Would the same effect occur if dry carbon paper were used in place of the soaked paper?

2. Would a solution other than table salt work as well or better?

3. What effect does varying the voltage have on the friction?

4. Are there practical applications of this phenomenon?

Voltage Retention

Bismuth, antimony, and some other substances retain a small fraction of an applied voltage for a short time after the applied potential has been removed. The aim of retaining the voltage is in the order of several seconds. Although a magnetic field may influence the effect, a complete explanation is not known. No practical application of this phenomenon has been made. Voltage retention is another laboratory curiosity destined to "sit on the shelf" until someone discovers its usefulness.

1. Can you measure this effect?

2. Try to devise a possible explanation of voltage retention.

3. Check the uses of these metals. Is there any way this effect could be applied where they are used?

Additional Questions in Physics

1. Can a water tunnel be constructed to find the best designs and attack angles for water skis?

2. Which instrument is more accurate for determining *g*, a simple pendulum or a physical pendulum?

3. Can extreme variations in temperature influence the decay rate of radioisotopes?

4. Why and how do stones skip on water? Will stones skip on sand?

5. Can a short-wave transmitter and receiver and a regular broadcast receiver operate simultaneously from one antenna?

6. Can the potential difference of the atmosphere (said to be well over 100 volts per meter) be measured? If so, can variations be used in weather forecasting?

7. What techniques are available for evaluating constants such as Avogadro's number and the charge-to-mass ratio for the electron? Which method produces the most reliable result?

8. Could the "red shift," usually explained as a Doppler shift, be due to some other reason? For instance does light get tired when transmitted a great distance?

9. If a large rubber sheet is stretched on a frame, can depressions in the sheet approximate a gravitational field when marbles are rolled across it?

10. The Kelvin Water-Dropper produces high-voltage electric discharges from dripping water. What theory can be developed to explain this phenomenon?

11. Can the thermal conductivity of a liquid be predicted on the basis of molecular or ionic constituents?

12. Does the exact pattern of tire treads make a difference in the tire's performance?

13. Does the glass in window panes "creep," that is, flow slowly? If so, how fast?

14. Is there a limit to the electrical voltage that can be produced by cells in series?

15. Is there a limit to the intensity of magnetic or electrostatic fields that can be formed?

16. Does a spinning cue ball colliding with a target pool ball produce postcollision paths of both balls different from that predicted for normal collisions?

IX. General

Altering Venus' Atmosphere

An astronomer recently suggested that the planet Venus might be made habitable for humans by altering its atmosphere. The "air" of Venus contains a high concentration of carbon dioxide which is not only toxic for man, but also, because of its high specific heat, is a contributing cause of the estimated 600° F surface temperature. This high temperature prevents the condensation of water. Oxygen has not been detected in the atmosphere of Venus.

The astronomer's plan calls for the introduction of unicellular algae into the atmosphere of Venus. As the algae carry out photosynthesis, they split water molecules releasing oxygen and pull in carbon dioxide molecules producing sugar. Eventually, the temperature would drop, rain would fall, and diatomic oxygen would occur in the new air.

1. Can algae be cultured in the atmosphere of a water cloud chamber? Do raindrops ever contain algae?

2. What is the highest concentration of carbon dioxide and the smallest concentration of oxygen that various species of one-celled algae can tolerate while they grow?

3. The carbon dioxide in the atmosphere of the earth is increasing. What general climatic effects can be expected? Can future earth mean temperatures be predicted?

4. How is a spectroscope used to analyze remote atmospheres?

5. How does temperature affect the growth of algae?

Collections

Generally, collections themselves do not constitute science projects. Well-classified and extensive collections of minerals, fossils, insects, or flowering plants, however, are enjoyable to gather and often are useful in solving science problems. A fossil collector might want to develop a system for the classification of crinoid rings where available keys in his locality make use only of the features of the rare crinoid head. Collectors of flowering plants might determine whether family grouping is possible on the basis of pollen structure. Collectors of insects might investigate the extent to which insects can be identified using wing venation as the only source for distinguishing characteristics.

An examination of a collection can raise many questions. For example, a tree leaf collection evoked the following questions.

1. Does the position of a leaf on a tree determine the leaf's size and intensity of green coloration?

2. Is there a pattern to the seemingly endless variations in the shape of sassafras leaves?

3. Does less light, frost, a combination of the two, or some other factor induce autumnal color change in leaves?

4. At what temperature will pine needles freeze?

Computers

A considerable amount of information can be dealt with in electrical circuitry that is based upon an "on" or "off" response. This basic "yes-no" circuitry can be expanded to respond "and," "either-or," "if, then," "remember-forget," "either, but not both." Our decimal numeration can be translated to a binary system which in use with the components of the "on-off" circuits make up so-called electronic brains.

The references listed below provide directions for assembling, simple logic circuits, and simple digital and analogue computers. Both pleasure and knowledge can be derived from building a puzzle machine or computer from an already proven printed circuit. The ultimate challenges and pleasures, however, are derived from designing and building a machine by one's self. Computer designs need not be limited to electrical circuits. Optical, chemical, biological, mechanical, and other devices can be designed for problem solving.

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C. L. Stone. *The Amateur Scientist.* Simon and Schuster, New York. 1960.

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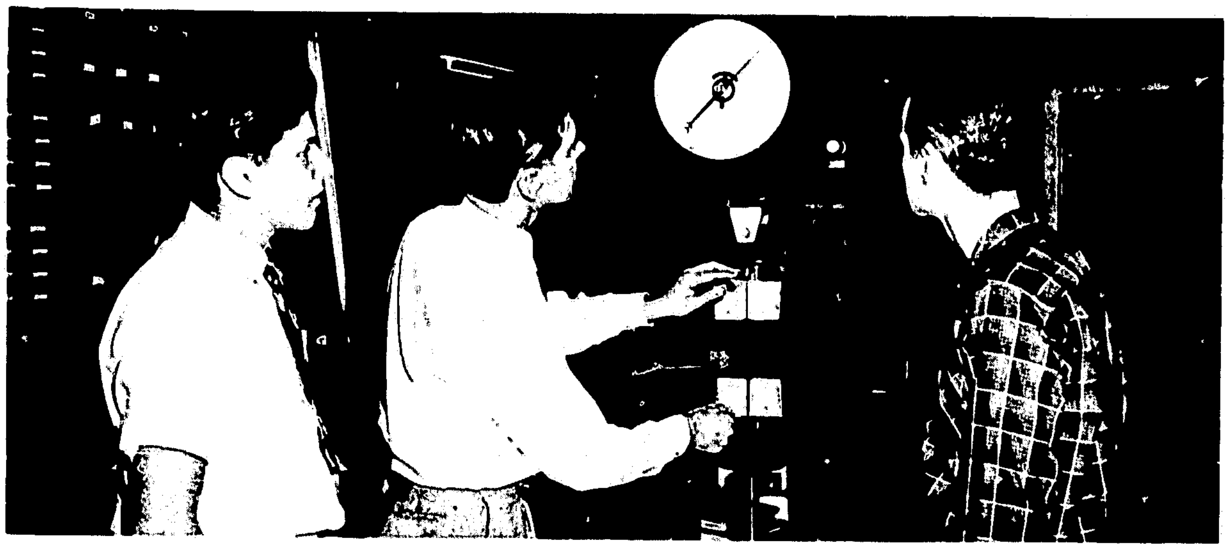

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Students can often arrange to use the facilities of industrial laboratories. These students are observing the results of measuring tensile strength with a special machine.

Cooperation Ventures

Certain problems can only be solved through the cooperation of observers geographically removed from one another. In astronomy, for example, the distance between the earth and the moon can be calculated from simultaneous measurements of the angle of the moon above the horizon when the distances between observers is known. The variations in rainfall in a county-wide area for a period of one year might reveal a range of reliability of a single "official" weather observation station. The genetic changes undergone by English sparrow populations since their introduction to the United States might be ascertained by comparing the characteristics of local specimens with specimens collected in other regions of America and England.

Each of the above projects requires contact among students with similar interests. Such contacts can be made by advertising in journals such as *Science World* or by writing to science classes or science clubs in regions where observation or collections can be made. Often science teachers have nationwide association with other science teachers who might help in organizing such projects.

ESP and PK

Extrasensory perception (ESP) and psychokinesis (PK) are sometimes referred to as pseudosciences. ESP involves mental telepathy and related phenomena. PK may be evidenced by mental processes affecting physical events. Both phenomena have gained scientific respectability through the work of J. B. Rhine at the parapsychology laboratory of Duke University, Durham, North Carolina.

1. Can thought transmission occur under carefully controlled conditions?

2. Can mental processes influence random events such as the rolling of dice?

3. Is plant growth affected by "wishing" for rapid growth?

Milkweed

The milkweed is one of the most common plants native to America. Aside from being a bane of the gardener and the sole food source of the monarch butterfly, milkweed is of minor importance in our economy. Attempts have been made to extract natural rubber from its latex. Botanists and entomologists have been fascinated by its trap-type pollination mechanism. Decorators have used the dried seed pods in fall and winter floral arrangements.

The seeds of the milkweed are covered with long silken hairs. Could these fibers be used as an insulating fill for gloves or comforters? What is the thermal conductivity of the material? As an insulating material, how does milkweed fiber compare with kapok, cotton, and wool? Could these fibers be used to make paper?

Purkinje Effect

Why are automobile taillights red? Can this color be seen best at night? The Purkinje effect notes that the human eye is less sensitive to light of longer wave lengths (*i.e.*, redder) under conditions of decreased illumination.

1. To what color (wave length) of light is the eye most sensitive when seen in different levels of illumination?

2. What is the most effective color combination for signs which promotes maximum readability?

3. Is the sensitivity of the eye affected by whether the colored light is reflected or emitted by a luminous source?

4. What color or combination of colors should automobile taillights be for maximum usefulness both day and night?

Reaction Time

Reaction time was one of the first psycho physical phenomena to be studied quantitatively. Helmholtz published results of the first reaction time experiments as such in 1850. Since then this phenomenon has been used in a variety of studies.

Reaction time has been used to test potential automobile drivers, airplane pilots, factory workers, and spacemen. It has been used to gain an understanding of the nervous system. Some researchers have attempted to connect basic individual intelligence with reaction time. Many coaches have sought to discover future athletes by measuring reaction times of young people.

1. Is there a sex difference in reaction times?

2. Which of the basic senses

stimulates the fastest reaction time?

3. Do reaction times differ when all the senses, except the one being used, are effectively shut off?

4. Does reaction time vary with muscular and/or mental exertion? Are there warming-up procedures that could produce optimum reaction times in people faced with a crucial need for speed?

5. Does exposure to diverting sense stimuli change the reaction time to a given stimulus?

6. What effect, if any, is produced on reaction time by drinking coke, coffee, or tea? By smoking cigarettes? By pep pills? By eating a candy bar?

School Day

The typical high school is scheduled to operate between 8:30 a.m. and 3:00 p.m. This choice of hours seems to be based more on a traditional working day than on a scientific basis. In recent years, overcrowding of schools has forced double sessions in some schools which may or may not have an adverse effect on the students.

Serious suggestions have been made that a longer school day be instituted as a result of the expanding amount of knowledge and skills required of high school graduates. These suggestions assume that an eight-hour day would permit one-third more learning than a six-hour day. This assumption may or may not be correct.

Psychological-physiological facts may have meaning for other aspects of high school as well as for scheduling the school day.

1. Most schools provide practice time for football, basketball, wrestling, field hockey, and other sports after school. Is this the best time for these activities?

2. Night classes are held in many cities. Are students mentally and physically equipped to do as well in these as in regular day classes?

3. Some people class themselves as "night people" and claim that alertness and activity are heightened then. Are there, in fact, night people? If so, can they be identified by tests?

4. Most schools have a tardiness problem. Why are students tardy? Are there ways to decrease tardiness? Is habitual tardiness an indication of some personal trait?

5. Many teachers feel that students in classes immediately after lunch do not utilize their full abilities. Is this true? If so, how could one's after-lunch alertness be improved?

6. Specific behaviors of students may vary through the day and have implications for making school more effective. Does body temperature, pulse rate, reflex time, ability to memorize, and dexterous ability vary through the day? A quantitative study of any one of these may produce significant results. The results may not be the same for different individuals or age groups.

7. Do students always have the same ability to learn? Through the week? Through the month? Through the year?

8. Are student creativity and originality more active at certain times through the day, week, month, and year?

9. Many people are easy to rouse from sleep in the morning and are "fast starters." Others are just the opposite. It has been suggested that this trait is due to a recessive gene. What evidence is there to test this hypothesis?

Science Fiction

"And when Joe Dindal, of Easterville, Iowa, kissed Rxcta Qr from Galaxy XZ 427, there occurred a violent explosion resulting in the complete annihilation of both individuals. . . .

"The team of space cryptographers labored for months attempting to crack the written language of the long-dead Martian civilization. Then one day in a Martian chemistry laboratory, a periodic table of the elements was discovered, and the language of Mars was revealed to Earthman."

Science fiction is imaginative writing, ideally founded upon facts and principles, but extending beyond the experiences of ordinary man. Much of the good science fiction is written by scientists who wish to speculate about the nature of the universe beyond the human senses or to teach nonspecialists abstract images about this world. Miss Qr was the spinning mirror image of Mr. Dindal. As when protons meet antiprotons, conversion of matter to energy results. The author of this tragic love story proceeded to discuss parity and the recent overthrow of parity. The second story points out the universality of the periodic law of the elements, the belief that matter as it is known probably exists throughout the universe and exhibits the same properties as noted on Earth.

Can you write good science fiction?

1. Analyze a number of science fiction tales of the past and present.
   - a. To what extent were the early authors able to accurately predict future developments and applications of science?
   - b. How much of the science of science fiction is compatible with present understandings?

2. Is science fiction an effective way to teach abstract science principles? Write a fiction story illustrating a concept not easily observed, e.g., the clock paradox. Obtain or write a comprehensive, straightforward discussion of the concept. Compare the interest and level of understanding of persons trying either or both methods.

3. Who are the readers of science fiction? Among this group of enthusiasts, how do reading tastes vary as to the kind of science fiction enjoyed?

Scientific Philately

Attention stamp collectors! A stamp collection could be used as the basis for a science project. You have probably seen examples of the wide variety of flora and fauna native to the issuing nation. Examples are: a snail, Cuba; mushrooms, Poland; butterflies, Switzerland; or birds and mammals, Angola. Many of the stamps can be purchased from dealers for modest amounts or traded from philatelists.

A science-related specialized stamp collection could be made of Mammals Typical of Geographical Regions, Animals of Commercial Importance, Plants from Which Useful Chemicals Are Obtained, or Insects Which Are Found Throughout the World. It might be interesting to use an identification key to the objects on these stamps to check the accuracy of the printed identification.

Scientists have been honored on many stamps. A specialized collection could be made of these with themes such as Chemists, Contributors to Modern Atomic Theory, and Pioneers in the Science of Electricity.

Useful references for specialized collections are Scott's, *Standard Postage Stamp Catalog* and Minkus', *Stamps of the World.*

Selenography

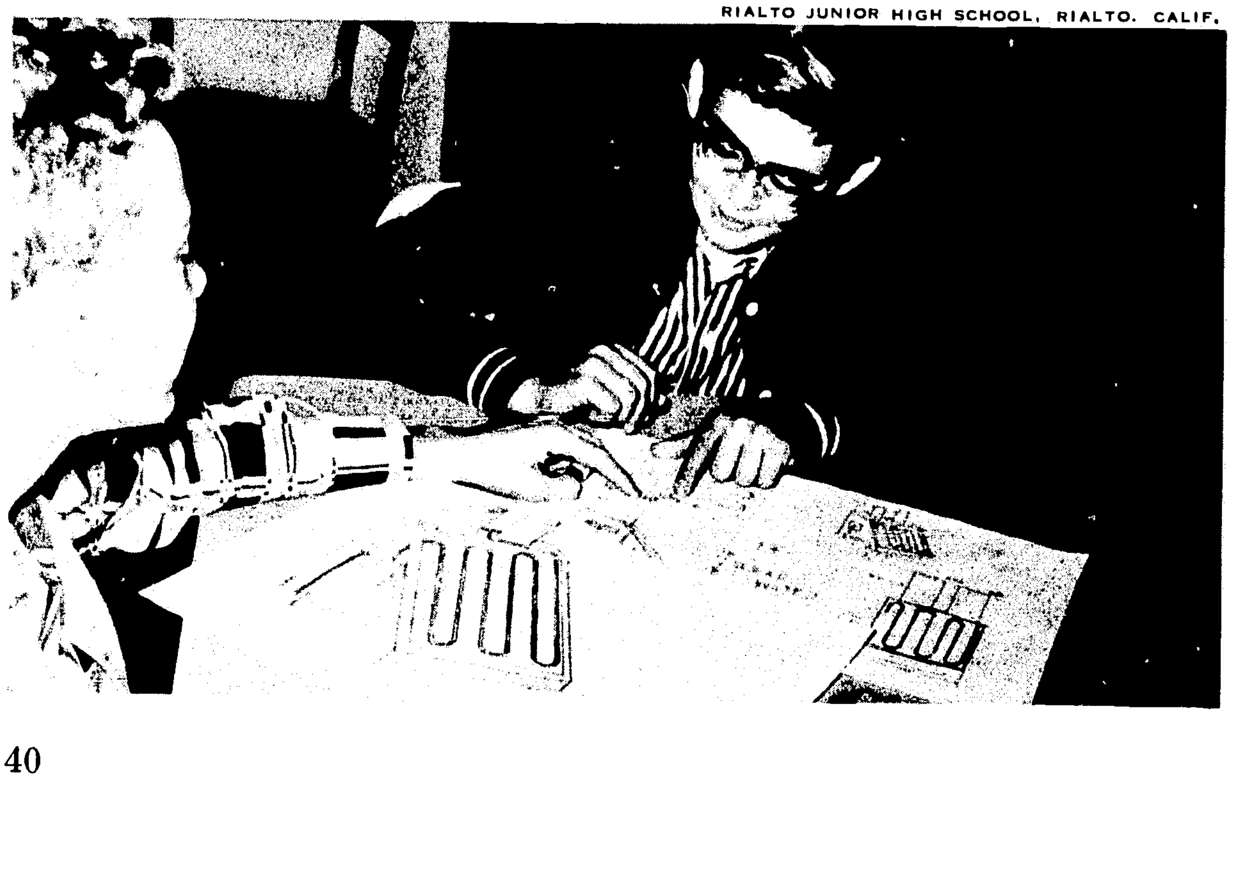
As one of the authors ponders the unknowns of selenography, he wonders whether readers will have just read and seen startling evidence that ends centuries of remote observation and speculation.

Selenography is the study of the surface geography of the moon. Outstanding features of the moon's surface include over 30,000 craters varying in diameter from about 150 miles to less than 300 yards, expansive plains or "seas," mountain ranges and peaks, fractures one-half mile wide to unknown depths, and giant streaks radiating from points on the surface.

One of the most puzzling questions is how were the craters formed? One theory claims a volcanic origin. How do volcanic craters on earth compare with lunar craters in feature? Another theory points out that bodies striking a deep dusty surface produce craters similar to those seen on the moon. Bomb scars on the surface of the earth as viewed from the air support a meteoritic theory. Can this theory be tested in the laboratory, using projectiles as meteors which strike a surface that simulates the lunar surface? How do natural earth meteorite craters compare with lunar craters?

From drawing board to production research. Two seventh-grade students contribute by preparing diagrams for construction of a solar water heater.

RIALTO JUNIOR HIGH SCHOOL, RIALTO, CALIF.



Other questions about the moon which can be investigated include:

1. How deep are the lunar craters? How high are the mountains of the moon?

2. What now known terrestrial mineral(s) are of the same color by reflected sunlight as those of the moon?

3. Where can the line between fact and fiction be drawn with regard to the influence of the moon on earth processes? The sexual phase of the South Pacific palolo worm *always* swarms immediately after the November full moon. The human menstrual cycle corresponds with the lunar cycle. The first frost of fall *always* occurs during the "bright of the moon."

4. What portion of the tidal phenomenon is caused by the moon?

5. How can atmospheric tides be measured?

6. Does terrestrial magnetism vary with the distance of the moon from the earth?

7. How can the reflecting power of the moon or any satellite be used to calculate its temperature?

8. From your direct observation can you predict the times of the next lunar and solar eclipses?

9. Could one or more satellites be designed to provide illumination for night vision? Would a continuous day upset the biological balance of the earth?

10. Why are the lunar streaks only visible during the full moon?

Sensory Stimuli

Most of what we know about the universe has been acquired by mankind through the senses. It is impossible to ask questions about nature to which answers cannot be obtained by the senses or instrumental extension of the senses.

Common experience tells us that a person's range of hearing is normally between 20 and 15,000 vibrations per second. This range varies among individuals and with age.

The range of stimulus intensity for other senses is not as well understood as that for sound. A study of any one of the senses from either a psychological, chemical, physical, or physiological point of view can lead to the exploration of many interesting phenomena.

1. What is the minimum concentration of salt in water that can be detected by taste? How does this compare with minimum concentrations for sweet and sour tastes? For other basic tastes?

2. How sensitive is the eye to small differences in brightness of luminous objects? Does the same sensitivity exist for all colors?

3. Does the presence of one taste substance mask the presence of another, and if so, how?

4. Insects, bloodhounds, and other organisms reportedly are able to detect very small traces of odor-causing substances. How sensitive are people to odors? What differences are there among individuals in this respect?

5. Is noise more distracting to people with musical interests than to those with little interest in music? Are unpleasant odors more distracting to people who prepare meals than to those who never go near a kitchen?

6. Can people become accustomed to distracting stimuli such as noise and odor and thereby be less affected by them?

7. What is the minimum temperature difference detectable by humans?

8. Can the sense of smell be used to determine end points in chemical titrations, assuming that a certain odorous substance is produced in most instances?

Shale

Shale is soft sedimentary rock generally originating from hardened mud. In many parts of the country shale deposits are several hundred feet thick. Although shale consists mainly of fine hydrous aluminum silicate grains useful in the manufacture of bricks and tiles, a wealth of fossil fuel, uranium, and other valuable minerals are known to be present. Considering the rapid depletion of easily obtained natural resources, we are forced to turn to sources of chemical energy and minerals where the expenditure to win them more nearly approaches, but does not equal, the power value of the fuel or the value of the mineral.

1. After detailed examination, what can you deduce about the geological origin of shale in your region or shale obtained from state geologists in other regions?

2. What materials are present in the shale and in what quantities? What is the radioactivity level of the shale measured with an electroscope or a Geiger counter?

3. How many BTU's per ton are there in this shale? How does it compare with other shales?

4. What are the qualities of bricks, tile, pottery, and cement which are made of this shale?

Soil Fertility

Soil is an exceedingly complex and variable sediment. It originates mainly from the decomposition and disintegration of bedrock through the action of wind, rain, glaciers, temperature change, and other weathering agents. The upper portion of the soil, called top soil, is composed of the more highly decomposed mineral matter and contains varying quantities of water-absorbent organic matter called humus. Below the top soil is the subsoil, usually less fertile, but supplying minerals and water to deeply rooted plants. Soil types seem to be greatly influenced by temperature, rainfall, and organisms interacting with an inorganic base that is present.

1. Can a satisfactory soil be synthesized by pulverizing the bedrock in your area and blending it with a water-absorbent organic material?

2. One characteristic of poor soil is its impermeability to water and air and its hardness which resists root growth. Soil conditioners are used to correct this characteristic. Three kinds are available. One is organic material such as peat or coffee grounds; another includes inorganic materials such as sand and vermiculite; and a third includes the synthetic and semisynthetic conditioners such as IBMA, Krilium, X 2, and X 19. Try each of the three types of conditioners in exposed subsoil. Which treatment is most effective?

3. Where the minerals, gases, and water in the environment of plant roots can be carefully controlled, can soilless plant culture (hydroponics) yield larger and healthier crops than soil gardening can produce?

4. An essential soil element for plants is nitrogen. From which of the following ions is it most effectively utilized: ammonium, nitrite, nitrate, cyanide, and nitride?

5. Are there any variations in the rates of capillary rise of water in various core samples of soil? What is the most effective hoeing depth for a particular plant in a clay soil?

Opportunities in Special Geographical Regions

The Cincinnati, Ohio region is world renowned for the variety, abundance, and quality of its fossils of the Ordovician period. Through the years, an impressive number of amateur and professional earth scientists developed in this area. Similarly, oceanography is a science suited for residents in coastal regions, smog abatement is of special interest for urban science students, while agricultural biochemistry is most meaningful to those who have lived on farms and have firsthand experience with farm science problems. The alert student seeking a research project might consider investigating problems unique to his region or community. In addition to having the natural resources available, he will discover that the area has probably attracted specialists who may serve as resource persons in an investigation related to their field.

If your region or community is:

A. Metropolitan.

1. How does the climate within the city depart from the reported norms established through observations at outlying weather stations?

2. Does the observable locus of corrosion in automobile bodies vary according to the use, place of storage, make of car, wax, undercoat treatment, or use of de-icing salts on certain streets?

3. What is the rate of dirt fallout in the city as compared with the country?

4. How do the accelerations developed by elevators in downtown buildings compare?

B. Rural.

1. Dirt roads tend to develop a surprisingly regular washboard surface. An explanation for this phenomenon and its means of prevention, other than paving, have long been sought.

2. An object moving over a rotating sphere is deflected relative to the surface of the sphere. In the earth's Northern Hemisphere moving objects should be deflected to the right. Does one bank of a river or one rail of a one-way train track show more wear due to this Coriolis effect, or does the effect work just for gases?

3. Is the population of small mammals and wild birds significantly influenced by the presence of free-roaming domestic cats?

4. Can cows inoculated with human disease microorganisms produce antibiotics that will appear in milk at an effective level for the human consumer?

5. Is it true that a riding horse can sense (smell, see, hear, and feel) the fear of a rider or a prospective rider?

C. Suburban.

1. What combination of fertilizer, weed killer, insecticide, variety of grass, height and frequency of grass cutting, and type of mower produces the most satisfactory lawns?

2. Are the suburbs producing a class of American people separate and distinct from other groups with regard to outlook on politics, entertainment and food preferences, prejudices, and contentment?

3. Are suburban areas quieter, healthier, or safer than city residential areas?

D. Coastal.

1. Consider studying the natural history of common but little-known marine invertebrates. After selecting and identifying a species or a group, problems can be identified regarding seasonal occurrence, abundance or density, food and feeding habits, variation, sex ratio, spawning habits, and growth rate.

2. What are the energy, structure, power utility, and weathering action of ocean waves?

3. Is the commercialized belief well founded that sea salts are a more healthful table salt than common iodized sodium chloride?

E. Mountainous.

1. Do people living at high altitudes compensate for the rarity of air by developing a higher density of red blood cells in the blood?

2. What biological difference can be noted and explained in the plant and animal communities on opposite slopes of the same mountain or hill?

3. Through direct observations, how much of the geologic history of an area can be reconstructed? What will the area look like in 50 million years?

F. Subtropical.

1. The reproductive activity of birds and lizards as measured by the size and development of gonads is largely influenced by the length of the day in temperate zones. In the Southern states, however, where day length is not as variable, what are the factors which seem to control the size and development of lizard gonads?

2. Perspiration is one heat regulatory mechanism of the body which can be easily measured by electrical resistance or cobalt chloride. Is a portion of the human population better suited to a warmer climate on the basis of their ability to physiologically adapt to higher mean temperatures?

G. Known for its bogs, deposits of quicksand, or asphalt.

1. What are the dimensions, age, and, origin of these formations?

2. If sampling or excavation is possible, for what organisms have these formations functioned as natural death traps?

3. Under what conditions will quicksand form? Can a study model be duplicated in the laboratory to give some data?

H. Desert.

1. Is water the only need of barren soil in this area? Where mineral deficiencies or excesses or pH extremes exist, how can the condition most economically be corrected or introduced?

2. What are the effects of using soil conditioners such as krilium on desert soil?

3. Do plants reflect the presence of specific minerals, that is, do certain plants prospect for "ores"?

I. Glaciated.

1. What information about the glacier(s), its direction of motion, speed, duration, mass, and origin can be deduced from observation of grooves in bed rock, moraines, erratics, and drainage systems?

2. What differences in soil chemistry, kinds of plants, and types of human communities can be noted on either side of terminal moraines?

Sports Psychology

In many bowling alleys the lanes to the extreme left and right are alongside walls. Many bowlers claim that the nearness of the wall affects their usual score. Subconsciously, the bowler may tend to stay away from the wall and thus change his normal bowling delivery. Many bowlers would be happy if these annoying walls could be painted or changed in some way to eliminate their distraction.

Bowlers (golfers too) are often distracted by unexpected sounds. Some basketball fans attempt to distract an opponent while he is shooting a free throw. Yet, the same fans believe that cheering will encourage their favorite team.

1. Is there a subconscious tendency to avoid walls when a person is engaged in some activity?

2. Are people adversely affected by the nearness of walls when studying or otherwise engaged in mental processes?

3. Is a person's depth perception affected by the color of the object perceived?

4. What color should the markings on a basketball court be to maximize the players' perception of boundaries? Would broken lines be more effective than solid lines?

5. What basketball uniform pattern or color would be easiest for players to recognize using peripheral vision?

6. Does the color of a basketball or football uniform make the wearer look larger, thereby gaining a psychological edge?

7. Are athletes in competition affected by cheering?

8. What, if any, is the source of the ten-point edge coaches believe a basketball team has by playing on its home court?

Subjective Time

Time is measured by physical devices which are notable for their constant and regular operation. The human "clock" often seems to proceed in jumps. We have all heard someone say, "Great Scott, is it time to go already?" Likewise we have experienced time flying or dragging. The time we perceive without reference to a clock is often called subjective time.

Recently, subjective time has gained interest in connection with manned space flights.

1. Can people learn to estimate short time intervals accurately? Is this ability related to any other ability or abilities?

2. What changes, if any, in one's physical environment cause great differences in estimated and measured time.

3. Can the relative accuracy of estimated time intervals be used as a criterion for interest in printed material? Can boredom be measured indirectly by time estimates?

4. Does the time sense change as a young person matures?

5. Does subjective time change when one looks back at an interval compared to the time estimate at the moment?

6. Are time estimates affected when one, two, three, or more of a person's senses are actively engaged in receiving stimuli?

Subliminal Perception

"EAT POPCORN," was the message on the screen in a movie theater in New Jersey, and popcorn sales increased that day by 60 per cent. But the strange thing about that advertising suggestion was that no one "saw" the message. It appeared on the screen for only 3×10^{-4} seconds, below a threshold of human vision. The subconscious response of the audience was thought to be caused by the phenomenon called subliminal perception by researchers.

1. "Sub-liminal" translates as "below threshold." What is the minimum duration for an image to persist and be consciously perceived by humans? Does light intensity affect this perception?

2. To what extent can subliminal suggestion manipulate the mind?

3. Many people believe subliminal suggestion is an invasion of personal rights. Should it be legally banned? How might one detect its illegal use?

Sunspots

In 1611, Johannes Frabricus reported that while observing the sun with a telescope he "was unexpectedly shown a black spot." Now known as sunspots, these cyclonic storms, covering areas on the surface of the sun sometimes in excess of 6×10^{9} square miles, can persist for months while they are moved across the face of the unevenly rotating sun. Although they are not really black, they have cooled adiabatically and only appear darker on the bright photosphere of the sun. Sunspot activity is associated with polar lights, magnetic storms, and weather phenomena. Major solar eruptions producing sunspots are thought to follow an eleven-year cycle.

1. By making daily sequential observations of the position of specific sunspots, can the rotational speeds of the sun be calculated for various solar latitudes?

2. Can eleven-year weather cycles be noted in the widths of tree rings?

During the International Geophysical Year, students of a science club became interested in the satellite tracking program known as "Moonwatch." As a result of their work, they were soon officially recognized as one of the 250 visual observation teams established in the United States. Other stations have since been established. The teacher poses with his students. Instruments were made available through the cooperation of local firms.

HOLY CROSS HIGH SCHOOL, NEW ORLEANS, LA.

3. Can sunspots be heard and analyzed by radio? Can they be chemically analyzed by spectroscopy or photographed through various filters?

Teen-age Drivers

All states require driving licenses. The minimum age for obtaining the license has been discussed in State legislatures, and the various states have come to a variety of conclusions. In Arizona, New York, Pennsylvania, and Vermont, 18 years is the minimum. Other states have set the age requirement between 14 and 18.

Most arguments about setting a minimum age limit for drivers' licenses revolve around personal responsibility, muscular coordination, reflex time, and similar properties. The age limits that have been set, however, are not usually the product of scientific evidence.

1. At what age should teen-age persons be eligible for drivers' licenses?

2. What individual characteristics determine whether a young person should be given a driver's license?

3. Do teen-agers actually undergo a period in their development when they lose agility *i.e.*, become clumsy?

4. Does a person's age affect his ability to estimate distance and speed, his reflexes, his tendency to overcorrect when steering a car, or react slowly to an emergency, etc.?

5. What effect do aggressive tendencies and other personality characteristics have on the quality of a driver?

6. Insurance rates for drivers under 25 are very high. Could another quantitative basis be used to measure the risk associated with insurance?

A separatory funnel is used to purify an enzyme which will be utilized in studying burns.

JIM KATZEL, BLACK STAR, NEW YORK, N.Y.

Toy Science

A number of toys and curiosities on the market today present some challenging problems.

1. What are the magnitude and direction of forces necessary to maintain the rotation of a hoola hoop? Why do adults seem to be less able to operate a hoop?

2. How does the "perpetually bobbing" drinking bird operate? Can the energy of the process be harnessed profitably?

3. What are the potentialities of water-air rockets? Can they be designed to develop enough specific impulse to achieve orbital velocity?

4. "Moon gardens" can be made from several kits. Essentially these kits consist of a sodium silicate gel and several packages of salt crystals such as copper sulfate, nickel sulfate, and ferric sulfate. The chemical reaction is double displacement, but why does the heavy metal silicate grow as it does?

5. What projectile velocities, measured with a ballistic pendulum, are realized with air guns, spring dart guns, bow and arrow, and water guns?

Weather Control

Man continues to be at the mercy of weather. Although the U.S. Weather Bureau scores 88 per cent in accuracy of predictions, man's control of weather is still very small. Certainly we can control temperature, pressure, and humidity in small and mostly enclosed systems, but our inability to end heat waves, mitigate cold spells, or dam wind storms doesn't qualify us as scientific masters of our atmospheric environment. Recently, however, we graduated from rain dances to cloud seeding. Much of the knowledge about controlling weather phenomena is derived from observations in contrived laboratory atmospheres.

1. Bombs have been suggested for use in reducing or redirecting hurricanes. What size of an energy

Projects may be based on experiments with home gardens and open doors to rewarding careers in plant science.

source is necessary to accomplish this task? Where in relationship to the cyclic storms should the bomb be detonated? To what extents can a whirlpool or whirlwind in a laboratory tank substitute for their atmospheric counterparts? What energy level explosive disturbance, placed where, effectively influences the storm?

2. Fogs are easily produced under laboratory conditions. What are some effective ways to dispel them?

3. What are the limits of effectiveness of the smudgepot method of frost prevention? Can this method be improved?

4. Which is more effective in seeding clouds, dry ice or silver iodide?

Whirlpools

Whenever a bathtub drains, a whirlpool often results. Whirlpools in the Northern Hemisphere are said to rotate counterclockwise, and those in the Southern Hemisphere, clockwise.

A simple apparatus could be devised to permit a study of whirlpools on a laboratory scale.

1. Do whirlpools continually rotate in the same direction?

2. What force or forces cause whirlpools?

3. Does fluid density affect whirlpool formation?

4. Is the ratio of diameter to depth the same for all whirlpools?

Additional General Questions

1. Why are some people more easily distracted from mental and/or physical tasks than other people?

2. In tire-recapping shops, a considerable amount of buffing dust, finely powdered rubber, is thrown away. Is there any practical use for this dust?

3. Why are sparks produced when flint and steel are struck together? What are the temperatures of the sparks?

4. Is subject matter which is easily learned also easily forgotten?

5. Tektites, small glassy fragments found on the earth, are thought to be extraterrestrial in origin. Can laboratory evidence be found to evaluate this hypothesis?

6. Fermentation of carbohydrates is a common process for producing ethanol. What strain of yeast is capable of producing the highest concentration of alcohol?

7. Are fingerprints, lines in the palm of the hand, or other wrinkles in the skin indicative of some characteristics of the individual? Are these specific patterns or types inherited?

8. Some types of shoe soles squeak when the wearer walks across certain types of floors. Why? Can some additive be found to diminish this effect?

9. Many people have increased their reading speed by special training and practice. Can a person's listening speed be improved beyond the rate to which we are accustomed?

10. Do people make their best physical and mental efforts when alone or with other people? Does competition have a stimulating or depressing effect on people?

11. A low signal-to-noise ratio has been given as the limiting factor in certain radio receivers. Must this ratio be a certain minimum value for audible signals?

PART THREE
References

X.
Ideas

American Journal of Physics. American Association of Physics Teachers, 57 East 55th Street, New York 22, New York.

Contains many technical articles above the level of most high school students. Occasional articles, however, describe new or unusual phenomena which could provoke projects. Also useful as a specialized source of information.

Journal of Chemical Education. Division of Chemical Education, American Chemical Society, The College of Wooster, Wooster, Ohio.

The principal articles in this monthly publication deal with chemistry on a specialized basis. A regular feature started in 1961 is "Chemical Projects—Research Ideas for Young Chemists." Each of the ideas is based on one or more articles in previous issues.

Physics Today. American Institute of Physics, 57 East 55th Street, New York 22, New York.

A monthly publication which features current problems and developments in physics that are of interest to all scientists as well as to physicists.

Science. American Association for the Advancement of Science, 1515 Massachusetts Avenue, N. W., Washington 5, D. C.

A weekly publication devoted primarily to current developments and thinking in pure science and its applications.

The Science Teacher. National Science Teachers Association, 1201 Sixteenth Street, N. W., Washington 6, D. C.

This monthly magazine is aimed at teachers of science. Many articles and a regular feature, "Classroom Ideas," suggest science projects.

Science World. Scholastic Magazines, Inc., 33 West 42nd Street, New York 36, New York.

A biweekly student publication which features depth presentation of phenomena, science news, and a variety of continuing departments of specific and general interest. The contents include a project section entitled, "Tomorrow's Scientists."

Scientific American. 415 Madison Avenue, New York 17, New York.

A monthly publication including articles of general interest in all areas of science. Projects are reported in the department entitled, "The Amateur Scientist."

The Amateur Scientist. C. L. Strong. Simon and Schuster, New York. 1960.

This book includes experiments and constructions, challenges and diversions in physical and biological sciences adapted from the project section appearing in *Scientific American.*

Atomic Radiation in the High School Science Class. Joe W. Tyson. Oldfriends' Books, 4923 Strass Drive, Austin 3, Texas. 1959.

A publication giving projects and experiments in the physical and biological aspects of atomic radiation. Also included are an extensive resource materials guide, a glossary, and a discussion of procedures.

Biological Investigations for Secondary School Students. Biological Sciences Curriculum Study. Johnson Publishing Company, Boulder, Colorado. 1961.

One hundred ideas for research in biology, presenting each problem with background, suggested approach and procedure, possible pitfalls, and references.

Demonstration Experiments in Physics. R. M. Sutton. McGraw-Hill Book Company, New York. 1938.

A collection of demonstrations and descriptions of apparatus for physics teachers to use in classrooms. Many of the demonstrations could be used as a starting point for student projects.

Geology and Related Sciences Sourcebook. The Duluth Conference of the American Geological Institute. Holt, Rinehart and Winston, Inc., New York. (To be published in 1962).

After the background of each of twenty-four areas in earth science such as "Historical Geology," "Weathering," "Glaciers and Glaciation," and "Geological Projects for Biology Courses," there are related problems, questions, demonstrations, projects, experiments, and references for follow-up study.

The Science Masters' Books. John Murray. London, England. 1931 (2), 1936 (2), 1950, 1955 (2), 1956.

A series of volumes each containing between 100 and 200 descriptions of experiments, demonstrations, and laboratory operations.

Science Projects Handbook, S. Moore, Editor. Ballantine Books—Science Service, 1719 N Street, N. W., Washington 6, D. C. 1960.

A collection of condensed reports in paperback form describing successful projects. Presents details of various project competitions.

Things to Do in Science and Conservation. Byron L. Ashbaugh and Muriel Beuschlein. The Interstate Printers and Publishers, Inc., Danville, Illinois. 1960.

Under the major groups Natural Resources and Man-Developed Resources, the authors have described phenomena as they relate to conservation. Many questions are asked which can serve as project starters.

Laboratory and Field Studies in Biology (Teachers Edition). Chester A. Lawson. Holt, Rinehart and Winston, Inc., New York. 1960.

This 500-page sourcebook details many open-ended experiments and projects organized in a sequence that accompanies a modern high school biology course.

Laboratory Experiments with Radioisotopes for High School Science Demonstrations. Samuel Schenberg. U. S. Atomic Energy Commission. Order from Superintendent of Documents, Government Printing Office, Washington 25, D. C. 1953.

Descriptions of twenty introductory experiments not requiring elaborate apparatus.

Physical Laws and Effects. C. F. Hix and R. P. Alley, Jr. John Wiley and Sons, Inc., New York. 1958.

Presents an extensive collection of effects, many of which are still laboratory curiosities. Each effect is accompanied by potential applications and several appropriate references and is presented through a description, an illustration, expected magnitude, and a short list of references.

Project Ideas for Young Scientists. J. K. Taylor, Editor. Joint Board on Science Education, Washington, D. C. 1960.

A collection, by science areas of topics which might provoke investigation through projects. Most of the topics refer to specific publications.

XI.
Information in Depth

The AAAS Science Book List. H. J. Deason. American Association for the Advancement of Science, Washington 5, D. C. 1959.
An excellent listing of books for general and specific reference. The books listed are grouped according to specific disciplines and are especially recommended for high school readers.

Applied Science and Technology Index. H. W. Wilson Company, New York. 1958-present.
A subject index of articles in specialized journals. Articles in the following journals could be especially helpful in project research: *Journal of Applied Physics, Corrosion, Geophysics, American Rocket Society Journal,* and *Plastics Technology.* These periodicals are not found in many libraries. It is possible that appropriate industrial libraries or individual members of the publishing societies would make them available to you.
If you have a strong background in a special area, some of the articles indexed could serve as the basis for a project.

The Education Index. H. W. Wilson Company, New York. 1929-present.
A cumulative subject index to several periodicals useful for science research. These periodicals include: *American Biology Teacher, American Journal of Physics, Journal of Chemical Education, School Science and Mathematics,* and *The Science Teacher.*

The Encyclopedia of Chemistry. G. L. Clark, Editor. Reinhold Publishing Corporation, New York. 1957.
Just what you would expect from the title. Technological, as well as the pure science aspects of chemistry are included in some detail.

Handbook of Chemistry and Physics. Chemical Rubber Publishing Company, Cleveland, Ohio. (published annually)
A ready reference book of chemical and physical data. Tables have been especially compiled from various authoritative collections and journals.

How to Know the Insects—Trees—Plant Families — Spring Flowers — Mosses and Liverworts—Land Birds—Fall Flowers—Immature Insects—Protozoa —Mammals—Beetles—Spiders—Grasses Freshwater Algae—Western Trees —Seaweeds—Freshwater Fishes. H. E. Jaques, William C. Brown Company, Dubuque, Iowa.
In addition to providing picture keys for the identification of groups of organisms, this series of book presents techniques in curating, collecting, as well as project suggestions.

McGraw-Hill Encyclopedia of Science and Technology. McGraw-Hill Book, Company, Inc., New York. 1960.
An up-to-date reference of 15 volumes to scientific and technological topics. Not historical, but written in a style satisfactory for college students and capable high school students. Good cross references to related subjects. This could well be the first reference consulted when undertaking any science project.

Reader's Guide to Periodical Literature. H. W. Wilson, New York. 1900-present.
A cumulative subject index of many periodicals, several of which are of special value as science references. These are: *Aviation Week and Space Technology, Bulletin of the Atomic Scientists, Consumer Reports, Electronics World, Scientific American, Science,* and *Sky and Telescope.*

Science Study Series. Anchor Books, Doubleday and Company, Garden City, New York. 1960.
Many of the monographs in this series are historical (e.g., *Michelson and the Speed of Light*); others describe current ideas concerning a specific phase of science (e.g., *Crystals and Crystal Growing*). Some are especially good for getting project ideas. Others are best for reference material. All are authoritative and well written. New titles are in the process of being added to the series.

Van Nostrand's Scientific Encyclopedia, Third edition. Princeton, New Jersey. 1958.
A general reference which ranges in complexity from simple to quite technical. If your project idea needs limitations, a reference like this may provide a picture of scope and variety of specialization.

Vistas of Science Series. Scholastic Book Services, 33 West 42nd Street, New York 36, New York.
Produced by the National Science Teachers Association in cooperation with Scholastic Book Services, the Vistas series include current and accurate data in a specialized field by a research scientist. Project suggestions developed by classroom teachers are also given. Available to date (with some 20 or more books to come) are the following: *Spacecraft, Experimentation and Measurement,* and *The Challenge of the Universe.*

XII. Techniques

Biology Projects. B. McAvoy, J. Ayers, J. C. Chiddix, and R. E. Dively. Science Publications, Normal, Illinois. 1959.
A wide range of demonstrations is included. Many of the techniques are useful in project work. A thoughtful reader could define some problems for research by reading parts of this book.

Book of Formulas, Recipes, Methods and Secret Processes. Popular Science Publishing Company, New York. 1945.
Actual formulas used in industry are given. A variety of subjects is covered, such as adhesives, perfume, luminous paint, cosmetics, artifical ice, silvering mirrors, and electroplating solutions.

Electronics, Project Ideas for Industrial Arts. Electricity Project Ideas for Industrial Arts. Research Project Ideas for Industrial Arts. The University of the State of New York, Albany, New York. (1957, 1958, and 1960 respectively.)
This series of monographs provides detailed directions for the construction of articles, most of which involve scientific principles. Included among these construction projects are plans for building a clock timer, a full-wave power supply, and a solar furnace.

Exhibit Techniques. Helen Miles Davis, Science Service, 1719 N Street, N. W., Washington 6, D. C. 1951.
A booklet devoted to ideas and suggestions on preparing projects for display purposes generally.

Exploring with Your Microscope. Julian D. Corrington, McGraw-Hill Book Company, New York. 1957.
This book thoroughly explores the uses of the microscope and the techniques of the microscopist in several branches of science. The last chapter concerns the work of the criminologist and may suggest many projects.

First Aid and Care of Small Animals. Ernest P. Walker. Animal Welfare Institute, 350 Fifth Avenue, New York 1, New York. 1955.
The publication provides primary information for maintaining vertebrates and invertebrates in captivity. A comprehensive bibliography will aid those wishing specialized references.

How to Do an Experiment. Philip Goldstein. Harcourt, Brace and Company, New York. 1957.
A comprehensive and practical analysis of scientific methods that can apply to problem-solving projects.

101 Simple Experiments with Insects. H. Kalmus. Doubleday and Company, Inc., Garden City, New York. 1960.
Directions for many techniques in solving project problems. This book might also generate some ideas for project investigations.

Methods and Materials for Teaching Biological Science. David F. Miller and Glenn W. Blaydes. McGraw-Hill Book Company, Inc., New York. 1938.
Although the first part of this book is useful only to teachers, Part II includes a wealth of information on collecting, culturing, and preserving, construction of biological instruments, and many suggestions about techniques involved in most biology-related projects.

The Radio Amateur's Handbook. West Hartford, Connecticut. The Amateur Radio Relay League. 1957.
Invaluable to the amateur who is interested in planning and working with circuits.

Scientific Instruments You Can Make. Helen Miles Davis. Science Service, Inc., Washington, D. C. 1954.
This book contains instructions for the construction of apparatus useful in research project work. Each written by a Science Talent Search winner.

Turtox Service Leaflets. General Biological Supply House, 8200 South Hoyne Avenue, Chicago 20, Illinois.
These short pamphlets (sixty currently in print) describe many techniques useful in project experimentation. Sample titles are: No. 6 Growing Fresh-Water Algae in the Laboratory, No. 52 Advanced Experiments in Bacteriology. Each leaflet costs three cents.