scale), the relativistic time modifications are negligible for travel within the solar system. For example, a man going to Neptune and stopping there, at an acceleration of 10 *g*, would spend 5 days on the trip but would gain only 1.5 minutes of time.

Then there is the question of the energy involved. The man who travels for 21 years at 1 *g* reaches a value of γ equal to 1.2×10^9, at which point his kinetic energy is utterly fantastic. If his vehicle weighs (at rest) 1 ton, then its energy content is equal, in round numbers, to the energy released in the annihilation of 10^9 tons of matter, or in the fission of 10^{12} tons of uranium; it would be sufficient to melt the entire crust of the earth to a depth of about 30 miles. The man who makes the more modest trip to Neptune at 10 *g* reaches $\gamma = 1.0025$, and the kinetic energy of his 1-ton ship (2×10^{17} joules) corresponds to that released in the fission of about 2 tons of uranium; because of the limited efficiency of rocket propulsion, the actual energy needed would be much greater. The use of such energy quantities in a rocket ship is so far beyond any foreseeable practical limits, and the time gain in that case is so small, that it is hard to picture a practical case of space travel in which the time dilatation can be considered important. This conclusion, of course, does not detract from the interest of the fundamental principles involved in the "clock paradox" (*4*).

References and Notes

1. W. H. McCrea, *Nature* 167, 680 (1951); 177, 784 (1956); 178, 681 (1956); 179, 909 (1957).
2. H. Dingle, *Nature*, 177, 782, 785 (1956); 178, 680 (1956); 179, 865, 1242 (1957).
3. F. S. Crawford, Jr., *Nature* 179, 35, 1071 (1957).

4. I would like to express my appreciation to Frank S. Crawford, Jr., David L. Judd, W. K. H. Panofsky, Henry P. Stapp, and Edward Teller for many useful discussions. Since I have not read widely in the literature of this subject, I apologize to any authors who may have already published any of the material given.

Image of the Scientist among High-School Students

A Pilot Study

Margaret Mead and Rhoda Métraux

This study is based on an analysis of a nation-wide sample of essays written by high-school students in response to uncompleted questions. The following explanation was read to all students by each administrator. "The American Association for the Advancement of Science (*1*), a national organization of scientists having over 50,000 members, is interested in finding out confidentially what you think about science and scientists. Therefore, you are asked to write in your own words a statement which tells what you think. What you write is confidential. You are not to sign your name to it. When you have written your statement you are to seal it in an envelope and write the name of school on the envelope. This is not a test in which any one of you will be compared with any other student, either at this school, or at another school. Students at more than 120 schools in the United States are also completing the statement and your answer and theirs will be considered together to really find out what all high-school students think as a group of people."

In general, the study shows that, while an official image of the scientist—that is, an image that is the correct answer to give when the student is asked to speak without personal career involvement—has been built up which is very positive, this is not so when the student's personal choices are involved. Science in general is represented as a good thing: without science we would still be living in caves; science is responsible for progress, is necessary for the defense of the country, is responsible for preserving more lives and for improving the health and comfort of the population. However, when the question becomes one of personal contact with science, as a career choice or involving the choice of a husband, the image is overwhelmingly negative.

This is not a study of what proportion of high-school students are choosing, or will eventually choose, a scientific career. It is a study of the state of mind of the students among whom the occasional future scientist must go to school and of the atmosphere within which the science teacher must teach. It gives us a basis for reexamining the way in which science and the life of the scientist are being presented in the United States today.

Objectives

Our specific objectives in this study were to learn the following.

1) When American secondary-school students are asked to discuss scientists in general, without specific reference to their own career choices or, among girls, to the career choices of their future husbands, what comes to their minds and how are their ideas expressed in images?

2) When American secondary-school students are asked to think of themselves as becoming scientists (boys and girls) or as married to a scientist (girls), what comes to their minds and how are their ideas expressed in images?

3) When the scientist is considered as a general figure and/or as someone the respondent (that is, the student writer) might like to be (or to marry), or, alternatively, might not like to be (or to marry), how do (i) the postive responses (that is, items or phrases, not answers) cluster, and (ii) the negative responses (that is, items or phrases) cluster?

4) When clusters of positive responses and clusters of negative responses are compared and analyzed, in what respects are the two types of clusters of responses (i) clearly distinguishable, and (ii) overlapping?

5) Is a generally positive attitude to the idea of science, an attitude which we

---

There is a great disparity between the large amount of effort and money being devoted to interesting young people in careers as scientists or engineers and the small amount of information we have on the attitudes those young people hold toward science and scientists. The Board of Directors of the AAAS has on several occasions discussed this disparity and the desirability of learning more about what high-school students actually think of science and scientists. This paper is one result of those discussions. Hilary Deason, director of the association's Traveling High-School Science Library Program, made all of the arrangements with the high schools and supervised the collection of the students' essays. The analysis of those essays and the preparation of this report were the responsibility of the two authors, Margaret Mead and Rhoda Métraux. Dr. Mead is associate curator of anthropology, American Museum of Natural History, New York, and Dr. Métraux is a research fellow at Cornell Medical College, New York.

are spending a great deal of money and effort to create, any guarantee of a positive attitude to the idea of science as a career?

Selection of Respondents

Two separate samples of respondents were used in the study: sample A, a nation-wide sample of high schools, and sample B, a sample of high schools with widely different economic and educational characteristics.

Sample A consisted of 132 public high schools (including one junior high school) that were selected from schools associated with the Traveling High-School Science Library Program sponsored by the National Science Foundation and administered by the American Association for the Advancement of Science. Of these, 118 were drawn from the high schools that participated in this program and an additional 14 from schools that qualified for the program but could not be included in it.

Sample B consisted of 13 special schools: four parochial schools, eight preparatory schools, and one public science high school. All these were from the eastern seaboard, selected to provide contrasts in educational and economic level to the smaller public high schools in the nation-wide sample (sample A). Sample B was collected after the homogeneity of the nation-wide sample had been ascertained.

The total enrollment of the schools participating in the study was 48,000. Schools with an enrollment of less than 300 students were asked to have each student complete one form; schools with an enrollment of more than 300 students were asked to complete 300 forms. The total sample (sample A and sample B) is drawn from the essays written by approximately 35,000 students, and the essays were kept together by the class, grade, and school from which the essays came.

The sample was randomized by drawing envelopes of these replies in groups that included three schools in one state, or three tenth grades, or all the separate classes in three schools, so that no essay was ever separated from the context in which it had been written.

Data-Gathering Instruments

We asked each high-school student respondent to write a brief essay on a topic set by an incomplete sentence which was printed at the top of a page, on which provision was also made for giving the school, the grade, the class or section, the age and sex of the respondent.

Three different forms were constructed, each with a different incomplete sentence. Each of these three sentences was chosen to elicit one major aspect of the image of the scientist.

Only one form was used in any one school (*2*), but the forms were so distributed that each form was used by at least one school in each state. These three forms are as follows.

Form I

Complete the following statement in your own words. Write at least a full paragraph, but do not write more than a page.

When I think about a scientist, I think of

Form II

If you are a *boy,* complete the following statement in your own words.

If I were going to be a scientist, I should like to be the kind of scientist who

If you are a *girl,* you may complete either the sentence above or this one.

If I were going to marry a scientist, I should like to marry the kind of scientist who

Form III

If you are a *boy,* complete the following statement in your own words.

If I were going to be a scientist, I would not *like to be the kind of scientist who*

If you are a *girl,* you may complete either the sentence above or this one.

If I were going to marry a scientist, I would not *like to marry the kind of scientist who*

Use of the three forms made it possible to distinguish between answers giving official versions of the image of the scientist and those involving the respondents personally, and the use of two forms of the personal question provided material on the links between negative and positive images, since many answers included responses relevant to both. Experience has shown that the way in which a question is phrased—that is, with a positive or with a negative emphasis—affects the phrasing of the answers by the respondents.

Analysis of Material and Problems of Validation

This study is based on qualitative data. The material reflects the way individuals feel and think about a subject as well as whether they will answer questions about the subject in the affirmative or the negative. The use of quantitative data, gathered primarily to count the number of individuals in any given group who will respond in one way or in another, is the more desirable technique when one is interested in whether individuals will agree or disagree with some stated opinion rather than how they feel or why they feel as they do. The check marks or brief responses gathered by quantitative studies are generally too sparse in the expression of feeling and imagery to permit the definition, or the redefinition, of shared attitudes; in such studies, attitudes which are assumed to exist are built into the questions.

The relative value of qualitative and quantitative studies has been debated in the behavioral sciences for some time. A resolution generally accepted at the present time is that the qualitative study is the method of choice for generating hypotheses, and the quantitative study the method of choice for testing hypotheses (*3*). When the problem is one of delineating a shared aspect of a society-wide set of images—rather than of answering questions on which or how many students may be expected to respond in a given way—a qualitative study is preferable.

The identification of the pattern in any large sample of essays and of the cognitive and emotional processes which underlie the attitudes reported by individuals is best accomplished by trained behavioral scientists. Because any one analyst, no matter how well trained, may have some blind spots and biases, and because analysts differ in their types of disciplined perception, we had six different analysts work independently with six subsamples of the total sample drawn from different states. Because one kind of material may be more useful than another in outlining a given area, we used —in addition to the essay samples from the 35,000 students—a variety of other kinds of materials as well.

We are assured that we have identified important themes in the material by the multiplicity of independent analyses and by the use of a variety of data. We are assured of the validity of our conclusions by a comparison of the independent work of the analysts and by the agreement on materials from different parts of the country.

Stages in Analysis and Validation

The stages in analysis and validation were as follows.

1) Sets of data were drawn from the main corpus by envelopes of answers, each set consisting of from 200 to 500 protocols, all from one state and including envelopes of answers to all three forms. Each of the six senior consultants was given a set of data. They worked in complete independence of one another until they met in conference to pool their results in discussion. This discussion was transcribed. The discussion indicated that the analysts were in agreement on the homogeneity of the attitudes found in the materials from different sections of

the country. On the basis of this preliminary working of the material from sample A, further collections for sample B (including provision for a control on the use of the words *American Association for the Advancement of Science*) were planned and carried out.

2) A detailed pattern analysis was performed on 1000 essays, chosen to represent both the homogeneous nation-wide sample of public schools (sample A) and the highly diversified schools (sample B). This analysis of responses (that is, items, phrases) both checked on the patterns identified by the senior analysts (among whom was included the analyst who made the detailed pattern analysis) and provided additional understanding of the patterns.

In making this analysis, essays from classes and schools were still kept together, so that each respondent could be placed and each essay could be placed within the major preoccupations of a class or a school. So some schools provided particularly clear material on the dichotomy between science as a subject for study and the personality of the scientist, or on ways in which an increasing sense of inadequacy was reflected in the rejection of science as a career. Everywhere it was possible to follow the divergent interests of boys and girls—as with the boys' interest in an active outdoor life and the girls' interest in the humanitarian aspects of medicine—but there were underlying assumptions shared by both sexes, such as the great importance of personal interests as a basis for career or marriage choice.

3) Fourteen graduate students were asked to report on smaller independent samples of essays. Graduate students were also enlisted to make collections of visual materials related to the image of the scientist in the culture of the United States today. Examples of this collection are illustrations from selected periodicals which present images of scientists, children's drawings made in response to the instruction "Draw a scientist," and the entire pictorial file from the public relations office of a pharmaceutical company.

4) Still another set of student essays from sample A was given to a seventh senior consultant, who had had no previous contact with any of the materials. Since she had not been involved in the earlier stages of the study, she could bring a fresh point of view to the final conference on the basis of which the report was written.

5) A final conference of the senior consultants was held, at which the preliminary findings were again reviewed, and the findings presented in this article were discussed in detail. There was general agreement that the findings effectively represented the data (*4*).

The Composite Image

In reading the following composite statements, it is important to realize that they do not represent literary descriptions written by the analyst but rather composites of the responses made by the students in their essays, so that each "composite image" is to be understood as being something like a composite photograph which emerges from a very large number of superimposed photographs. Each phrase (response) both stands for a family of phrases (responses) which were used throughout the essays and is itself a recurrently used phrase (response). The phrases have been grouped in relation to themes, as they occur in the essays, but reference to the themes might occur in any order in the essays. It is important to realize that in organizing for presentation here the positive and the negative versions of the composite image of the scientist, the analyst has separated out from the answers the positive phrases (responses), on the one hand, and the negative phrases (responses), on the other hand, as an analytic device, whereas in the essays both occur—or may occur—together in a variety of combinations.

Before the image of the scientist is discussed, it will be useful to look at the way "science" appears in these essays. In the following composite statements, italics indicate the words and phrases (responses) used; detailed examples are given in parentheses, and explanatory notes in square brackets.

Science

Science is a very broad field which may be seen as a single unit (*science is very important,* or *I am not interested in science*), as a melange (*medicine and gas and electric appliances*), or as composed of entities (*biology* and *physics* and *chemistry* . . .) linked together by the personality of the *scientist.*

Science is natural science with little direct reference to man as a social being except as the products of science—*medicine* and *bombs*—affect his life. The subjects of science are *chemistry* and *physics* (*laboratories, test tubes, bunsen burners, experiments* and *explosions, atomic energy, laws* and *formulas* . . .), *biology-botany-zoology* (*plants* and *animals* [that is, as materials for laboratory work], *microscopes, dissection, the digestive system, creepy* and *crawly things* . . .), *astronomy* (*the moon, stars, planets, the solar system, outer space, astronomers, astrologers* [*sic*], *telescopes, space ships* . . .), *geology* (*the earth, rocks, mines* and *oil wells, out of doors* . . .), *medicine* (*cures for TB, cancer, heart disease,* and *polio, research, serums* . . .); *archeology* (*exploration, ancient cities, early man, fossils, digging* . . .). *Mathematics* is not a science but a tool and a measure of scientific aptitude.

The methods of science are *research* and *experimentation, invention, discovery, exploration, finding out new things* and *new ways of improving old ones.* Science means *doing* and *making: hard work*—not imagination—is the source of knowledge and the means of accomplishment.

The focus of science is upon the present. The past is important only as it is left behind (*without science we would still be living in caves*) and the future as a foreseeable goal (when we *find a cure for heart disease, see if there is life on Mars, discover new fuels. . .*). But as the past closes in behind us, the future opens to the curious (*there is still so much to discover*) into the yet unknown.

In thinking about science, different sorts of linked images occur which may be bracketed together when science is rejected or may be included when positive preference is expressed for one of a pair. So, science may be *theoretical* or *applied,* and either of this pair can be seen as more of a whole and be accepted (that is, the man in the laboratory is visualized as working through the whole problem; or the engineer can see the finished road), while the other is seen as partial and is rejected (that is, the engineer is visualized as working only on the end-product; or the man in the laboratory never sees the plan carried out). Likewise, science can be carried out *in the laboratory* or in a *far away place*; it may involve large-scale action (*traveling, digging, exploring, constructing, flying through space* . . .) or the skills of fine detail (*gazing through a telescope, poring over a microscope, dissecting, solving equations* . . .). The goals of science may be humanitarian (*working to better mankind, finding cures, making new products,* developing *programs for atoms for peace* . . .), or, in contrast, they may be either individualistic (*making money, gaining fame and glory* . . .) or destructive (*dissecting, destroying enemies, making explosives* that *threaten* the *home,* the *country,* or *all mankind* . . .).

Since, by implication, science is the source of unlimited power, its practitioners should have the highest and the most selfless motivations to use only its constructive possibilities—or its destructive possibilities only constructively—for the *welfare of their country* and the *betterment of people, the world,* and *all mankind.*

The Scientist

The Shared Image (*5*)

The scientist is a man who wears a white coat and works in a laboratory. He is elderly or *middle aged and wears glasses. He is small,* sometimes *small and* *stout,* or *tall and thin. He* may be *bald. He* may *wear a beard,* may be *unshaven* and *unkempt. He* may be *stooped and tired.*

He is surrounded by equipment: test tubes, bunsen burners, flasks and bottles, a jungle gym of blown glass tubes and weird machines with dials. The sparkling white laboratory is full of sounds: the bubbling of liquids in test tubes and flasks, the squeaks and squeals of laboratory animals, the muttering voice of the scientist.

He spends his days doing experiments. He pours chemicals from one test tube into another. He peers raptly through microscopes. He scans the heavens through a telescope [or a *microscope!*]. *He experiments with plants and animals, cutting them apart, injecting serum into animals. He writes neatly in black notebooks.*

The image then diverges.

POSITIVE SIDE OF THE IMAGE OF THE SCIENTIST

He is a very intelligent man—a genius or *almost a genius. He has long years of expensive training—in high school, college,* or *technical school,* or perhaps even beyond—during which *he studied very hard. He is interested in his work and takes it seriously. He is careful, patient, devoted, courageous, open minded. He knows his subject. He records his experiments carefully, does not jump to conclusions, and stands up for his ideas even when attacked. He works for long hours in the laboratory, sometimes day and night, going without food and sleep. He is prepared to work for years without getting results and face the possibility of failure without discouragement; he will try again. He wants to know the answer. One day he may straighten up and shout: "I've found it! I've found it!"*

He is a dedicated man who works not for money or fame or self-glory, but—like Madam Curie, Einstein, Oppenheimer, Salk—for the benefit of mankind and the welfare of his country. Through his work people will be healthier and live longer, they will have new and better products to make life easier and pleasanter at home, and our country will be protected from enemies abroad. He will soon make possible travel to outer space.

The scientist is a truly wonderful man. Where would we be without him? The future rests on his shoulders.

NEGATIVE SIDE OF THE IMAGE OF THE SCIENTIST

The scientist is a brain. He spends his days indoors, sitting in a laboratory, pouring things from one test tube into another. His work is uninteresting, dull, monotonous, tedious, time consuming, and, though he works for years, he may see no results or may fail, and he is likely to receive neither adequate recompense nor recognition. He may live in a cold-water flat; his laboratory may be dingy.

If he works by himself, he is alone and has heavy expenses. If he works for a big company, he has to do as he is told, and his discoveries must be turned over to the company and may not be used; he is just a cog in a machine. If he works for the government, he has to keep dangerous secrets; he is endangered by what he does and by constant surveillance and by continual investigations. If he loses touch with people, he may lose the public's confidence—as did Oppenheimer. If he works for money or self-glory he may take credit for the work of others—as some tried to do to Salk. He may even sell secrets to the enemy.

His work may be dangerous. Chemicals may explode. He may be hurt by radiation, or may die. If he does medical research, he may bring home disease, or *may use himself as a guinea pig,* or *may even accidentally kill someone.*

He may not believe in God or *may lose his religion. His belief that man is descended from animals is disgusting* (6).

He is a brain; he is so involved in his work that he doesn't know what is going on in the world. He has no other interests and neglects his body for his mind. He can only talk, eat, breathe, and sleep science.

He neglects his family—pays no attention to his wife, never plays with his children. He has no social life, no other intellectual interest, no hobbies or relaxations. He bores his wife, his children and their friends—for he has no friends of his own or *knows only other scientists —with incessant talk that no one can understand;* or else *he pays no attention* or *has secrets he cannot share. He is never home. He is always reading a book. He brings home work and also bugs and creepy things. He is always running off to his laboratory. He may force his children to become scientists also.*

A scientist should not marry. No one wants to be such a scientist or *to marry him.*

Discussion

The "official" image of the scientist—the answer which will be given without personal involvement—which was evoked primarily in form I, but which recurs in the answers to all three forms, is a positive one.

The scientist is seen as being essential to our national life and to the world; he is a great, brilliant, dedicated human being, with powers far beyond those of ordinary men, whose patient researches without regard to money or fame lead to medical cures, provide for technical progress, and protect us from attack. We need him and we should be grateful for him.

Thus if no more than form I had been asked, it would have been possible to say that the attitude of American high-school students to science is all that might be desired.

But this image in all its aspects, the shared, the positive, and the negative, is one which is likely to invoke a negative attitude as far as personal career or marriage choice is concerned. While the rejection in the negative image is, of course, immediately clear, the positive image of very hard, only occasionally rewarding, very responsible work is also one which, while it is respected, has very little attraction for young Americans today (7). They do not wish to commit themselves to long-time perspectives, to dedication, to single absorbing purposes, to an abnormal relationship to money, or to the risks of great responsibility. These requirements are seen as far too exacting. The present trend is toward earlier marriage, early parenthood, early enjoyment of an adult form of life, with the career choice of the man and the job choice of the woman, if any, subordinated to the main values of life—good human relations, expressed primarily in terms of the family and of being and associating with the kind of human being who easily relates to other people.

To the extent that any career—that of diplomat, lawyer, businessman, artist, aviator—is seen as antithetical to this contemporary set of values, it will repel male students as a career choice and girls as a career for their future husbands. But it is important to see also the particular ways in which the image of a scientific career conflicts with contemporary values. It divides girls and boys. The boys, when they react positively, include motives which do not appeal to the girls—adventure, space travel, delight in speed and propulsion; the girls, when they react positively, emphasize humanitarianism and self-sacrifice for humanity, which do not appeal to the boys. The girls reject science, both as a possible form of work for themselves, concerned with things rather than with people, with nonliving things (laboratory animals, not live animals; parts of anatomy, not living children), and for their husbands, because it will separate them, give their husbands absorbing interests which they do not share, and involve them in various kinds of danger. In earlier periods, when career choices and marriages occurred later, the girls' attitudes might not have mattered so much; they are very important today, on the one hand, because girls represent a principal untapped source of technical skill, and, on the other hand, because, with present adolescent social patterns, paired boys and girls spend a great deal of time discussing the style of their impending marriage and parenthood and the relationship of the boy's career choice to the kind of home they will have.

The image of the scientist's relationship to money also presents a problem, in a period of full employment, to young people who think that an adequate income is something that should be taken for granted. The scientist is seen as having an abnormal relationship to money. He is seen either as in danger of yielding to the temptation of "money and fame," or as starving and poor because of his integrity. The number of ways in which the image of the scientist contains extremes which appear to be contradictory —too much contact with money or too little; being bald or bearded; confined work indoors, or traveling far away; talking all the time in a boring way, or never talking at all—all represent deviations from the accepted way of life, from being a normal friendly human being, who lives like other people and gets along with other people.

Specific Indications about the Teaching of Science

From the standpoint of teaching, it is important to realize how the present image of scientific work lacks any sense of the delights of intellectual activity; the scientist works patiently and carefully for years, and only when he finds out something does he shout with joy. This lack of any sense that intellectual activity is rewarding in itself can be related to the lack of any mention of living things, plant, animal, or human, in the materials with which the scientist is believed to work. Plants and animals appear only as dead objects for dissection; the human body, as organs or systems studied in the laboratory and treated in medicine; whole human beings appear only as the dead denizens of dead and buried cities, and most of the scientists about whom they read are also dead. The lack of any sense of enjoyment can also be related to the central role given to mathematics as a tool, without any emphasis on the delights of observation, as in early natural history studies or in the perception of regularities and connections in the world around them, or between themselves and the world around them.

Because the materials were analyzed class by class and school by school, the study has also yielded, as a by-product, certain sidelights on science teaching: on the importance of participation as opposed to passive watching, on the role which the personality of the teacher plays in attitudes toward science, on the effect on the rest of the class of the presence in it of one type of exceptionally gifted child.

One of the most recurrent responses is an expression of active boredom, the phrase, "I am not interested in science," or in a particular science course (chemistry or physics), followed occasionally by highly emotional expressions of fury and hatred of particular activities which are being demonstrated. "Interest" and "active enjoyment" seem to be so closely related that the student seated in a classroom who has to watch things being poured from one test tube to another or listen to a string of unrelated facts becomes permanently alienated. General science courses seem to be the ones in which this attitude toward science is characteristically invoked, except when a gifted teacher gives it some special emphasis. When mathematics is seen as the key ability on which all future scientific work is based, not liking and not being able to do mathematics become a specially weak point in the circle of the students' interests.

In contrast, other activities are defined as nonscientific because they are absorbingly interesting: "watching things grow that I have planted," or "working on my hot rod car."

The role of the teacher—as reflected in the comments of a whole class—is an exceedingly interesting one. The disliked teacher is personalized and vivid, but the teacher who has obviously been very successful and has caught the imagination and enthusiasm of the whole class does not emerge as a person at all but, instead, sinks into the background of good classroom conditions, together with "good laboratory equipment." Special aspects of the disliked teacher are commented on in detail. He may be described as an outsider, a stranger, with unusual habits of dress and manner, who does not know his subject well, who cannot talk about anything but his subject, who lives alone without the slightest tie to the community, who is "stuck-up and who is too busy for anyone but himself." It is easy to see how the only male teacher in the school presents special problems to the boys, if he himself is a figure they reject, and how easily the sphere of work for which he stands may be rejected also. So one boy writes, "Anyone who digs our teacher's gab is a square as well as being queer." Some of these consequences undoubtedly flow from the convention in the United States that, ideally, science should be taught by men, with the result that men who might be more successful teachers in some other field are forced into teaching a subject which they dislike and in which they have no special competence. Similarly, foreigners and refugees—if male—may have a better chance to get positions as mathematics and science teachers than they have in other fields (*8*).

The significance of the lack of particular mention of the good science teacher is equally important, for it is related to the lack of invocation of authority by the students, who state their opinions about science—even those obviously related to a particular teacher—as their own. Only when they disagree, when they wish to attack the current image of science as a good thing from a minority position—that is, from the viewpoint of some fundamentalist religious position which they accept—do they invoke authority. It is related also to the situation in American culture where, through generations, there has been a break between immigrant parent and native-born child. In this new setting, the European tendency for children to identify with the personality and occupation of the parents has been replaced by a tendency to follow the style set by members of one's own generation, especially those in one's own local school clique.

In the classroom, a disliked fellow-student who is regarded as a future scientist may also be described in some detail, as students say they do not want to be the kind of scientists who "go about with their noses in a book, looking superior." But in those classrooms where everyone has been committed to the joy of some experiment or project, no individuals emerge: it is impossible to say what is the sex, age, nationality, and personality of the teacher.

In summary, it may be said that where science teaching is successful, the teacher has created a situation in which his or her (one does not know which) personality sinks into the background, and in which no one student stands out as so especially gifted and preoccupied as to rouse annoyance in the class. Students and teacher appear to have worked as a group, accepting science as a part of *their* lives, preoccupied with no specific identified individuals.

Recommendations

Mass media. Straight across the country there is a reflection of the mass media image of the scientist, which shares with the school materials the responsibility for the present image. Alterations in the mass media can have important consequences in correcting the present distorted image if such changes are related to real conditions. Attempts to alter the image, in which the public relations department of a particular company represents its research personnel with crew cuts and five children may improve the recruitment program of single companies, but do so only at the expense of intensifying the negative aspects of the image for the country as a whole.

What is needed in the mass media is more emphasis on the real, human rewards of science—on the way in which scientists today work in groups, share common problems, and are neither "cogs in a machine" nor "lonely" and "isolated." Pictures of scientific activities of groups, working together, drawing in people of different nations, of both sexes and all ages, people who take delight in their work, could do a great deal of good.

The mass media could also help to break down the sense of discontinuity between *the scientist* and other men, by showing science as a field of endeavor in which many skills, applied and pure, skills of observation and of patient, exact tabulation, flashes of insight, delight in the pure detail of handling a substance or a material, skills in orchestrating many talents and temperaments, are all important. This would help to bring about an understanding of science as a part of life, not divorced from it, a vineyard in which there is a place for many kinds of workers.

The schools. The material suggests the following changes which might be introduced in educational planning.

1) Encourage more participation and less passive watching in the classroom, less repeating of experiments the answers to which are known; give more chance to the students to feel that they are doing it themselves. A decrease in the passive type of experience found in many general science courses seems particularly necessary.

2) Begin in the kindergarten and elementary grades to open children's eyes to the wonder and delight in the natural world, which can then supply the motive power for enjoyment of intellectual life later. This would also establish the idea of science as concerned with living things and with immediate—as contrasted with distant—human values.

3) Teach mathematical principles much earlier, and throughout the teaching of mathematics emphasize nonverbal awareness (*9*): let children have an opportunity to rediscover mathematical principles for themselves.

4) Emphasize group projects; let the students have an opportunity to see science as team work, where minds and skills of different sorts complement one another.

5) Emphasize the need for the teacher who enjoys and is proficient in science subjects, irrespective of that teacher's sex; this would mean that good women teachers could be enlisted instead of depending on men, irrespective of their proficiency. Since it would seem that the boys do not need to identify with an adult male as a teacher, this should leave us free to draw on women as a source of science teachers.

6) Change the teaching and counseling emphasis in schools which now discourages girls who are interested in science. This would have many diffuse effects: on the supply of women teachers and of women in engineering, on the attitudes of girls who are helping boys to choose careers, and on the attitudes of mothers who are educating their small children in ways which may make or mar their ability to deal with the world in scientific terms.

7) Deemphasize individual representatives of science, both outstanding individuals like Einstein—whose uniqueness simply convinces most students that they can never be scientists—and the occasional genius-type child in a class. (This type of child, who represents only one kind of future scientist and who is often in very special need of protection from the brutalities of his age mates, should probably be taken out of small, low-level schools, and placed in a more protected and intellectual environment.) Instead, emphasize the sciences as fields, and the history of science as a great adventure of mankind as a whole. (The monotonously recurrent statement "if it weren't for scientists we would still be living in caves" is an insult to the memory of millions of anonymous men who have—each in his way—made further advances possible.)

8) Avoid talking about *the scientist, science,* and *the scientific method.* Use instead the names of the sciences—biology, physics, physiology, psychology—and speak of what a biologist or a physicist does and what the many different methods of science are—observation, measurement, hypotheses-generating, hypotheses-testing, experiment.

9) Emphasize the life sciences and living things—not just laboratory animals, but also plants and animals in nature—and living human beings, contemporary peoples, living children—not the bones and dust of dead cities and records in crumbling manuscripts. Living things give an opportunity for wonder and humility, necessarily less present in the laboratory where students deal with the inanimate and the known, and contact with living things counteracts the troubling implication that the scientist is all powerful.

Conclusion

This report is not in any way a statement of the proportion of high-school students who will choose science as a career. It is a discussion of the state of mind of fellow-students, among whom the occasional future scientist must go to school, of the degree of personal motivation necessary to commit oneself to science, and of the atmosphere within which the science teacher must teach. Since most high-school students' attitudes closely reflect those of their parents, it is also an indication of the climate of opinion in which parents may be expected to back up their children in choosing science as a career, citizens may be expected to vote funds for new laboratories, and voters may be expected to judge Congressional appropriations for science education.

References and Notes

1. To control any possible influence which the wording of this statement might have, part of sample B was collected without reference to the association. No difference in the formulation of the replies was found when the association was mentioned and when the association was not mentioned.
2. In six of the schools included in sample B, all three forms—to be used by different classes—were sent to the same school.
3. There are a number of different quantitative studies of the broader subject under way: those directed by H. H. Remmers in the Division of Educational Reference at Purdue University, on high-school students' attitudes toward science; a study at the Survey Research Center at the University of Michigan on attitudes of the public toward science writing; two studies under the Science Manpower Project at Teachers College, Columbia University, one by Hugh Allen, on "Attitudes toward science and scientific careers: a research inventory for New Jersey high-school seniors," and a second by Frances Hall, on science teachers' attitudes toward science. The Interim Committee on Studies on the Social Perception of the Satellite Program and Personnel, under the chairmanship of Donald Michael of Dunlap Associates, Stamford, will also cover some overlapping areas.
4. For assistance in this study through the Institute for Intercultural Studies, which cooperated with the American Association for the Advancement of Science, we wish to thank Ruth Bunzel, Edith Cobb, Natalie Joffe, Martha Wolfenstein, Mark Zborowsky, also graduate students in Columbia University anthropology courses GS 271-2 and GS 198, and, for criticism of the report, Robert Weiss of the Survey Research Center, University of Michigan.
5. A few of the more mature students realize that this picture is stereotyped and incomplete. So, for instance, having described the scientist as the "man in the white coat," students continue: "On second thought—he might equally well be seining a small stream, feeding facts into an electronic computer, or injecting a radioactive fluid into the veins of a monkey" (boy, 17, 12th grade). "I realize that there is more than microbiology [that is, the man in the white coat] to science. Therefore, I think of the atom, and somehow always of old men, working on various bombs and reactors. When I think of the use of atoms for peace, I think of young men working in offices. I don't know why" (girl, 14, 10th grade). "At the word *science,* I can imagine so much. The scope is unlimited and I sometimes do not connect the two words [*science* and *scientist*] any further than the laboratory. But if I could put the two together, a scientist would become more of an adventurer, a romanticist, than a figure who is nothing but a human IBM machine" (boy, 15, 10th grade).
6. When evolution is mentioned, it is mentioned negatively. It is impossible to tell what the absence of other than negative references to evolution means. In Remmers' study [H. H. Remmers and D. H. Radler, *The American Teenager* (Bobbs-Merrill, Indianapolis, Ind., 1957), p. 171] 40 percent of the teenagers checked "No," to the statement "Man has

evolved from lower forms of animals"; another 24 percent checked "Don't know"; 35 percent checked "Yes."

7. In this statement, we draw not only on the attitudes in this study but on a wide variety of other materials on the attitudes of contemporary young Americans.
8. The other side of this picture is sometimes seen in comments made by foreigners who have entered the sciences because Americans think they require less of a knowledge of the culture, and who because of their science training can get teaching positions in the schools. After a year or two of teaching in small-town schools, the foreign-born teacher flees back to the cities where he has friends or at least can live anonymously. (Based on life-history data from Chinese informants in the Chinese section of the Study Program in Human Health and the Ecology of Man, New York Hospital–Cornell Medical College, New York.)
9. Studies of the College Entrance Examination Board Commission on Mathematics and the University of Illinois Committee on School Mathematics give promise of bringing about improvement in mathematics instruction. A study of junior-high-school mathematics will be undertaken at the University of Maryland this fall. There is more to be done, especially in the elementary grades, and state departments of education should be encouraged to establish state committees which can determine how work now in progress at the national level can be made effective in local schools. The Poloidiblocs, developed by Margaret Lowenfeld of the Institute of Child Psychology, 6 Pembridge Villas, London, W.11, are an important addition to the equipment for teaching young children mathematics.

A. S. King, Spectroscopist

Arthur Scott King was born 18 January 1876 in Jerseyville, Illinois. In 1883 the family moved to Santa Rosa, California and, about 1890, to Fresno, where Arthur received his secondary education. In 1895 he entered the University of California at Berkeley; here, in 1899, he received the B.S. degree and, in 1901, the M.S. In 1903 he received the first Ph.D. degree in physics ever awarded by the university. He was assistant instructor in physics at the university from 1901 to 1903. He spent the years 1903 and 1905 in Bonn, Germany, where he was a pupil of H. Kayser, who was then publishing the early volumes of his monumental *Handbuch der Spectroscopie*.

King's professional career really began in 1905, when he was appointed instructor in physics at the University of California. In January 1908 he was appointed superintendent of the physics laboratory at the Mount Wilson Solar Observatory, as it was called at that time. Here he remained until his retirement in 1943, and here, under George E. Hale's dynamic leadership, King chose detailed studies of atomic spectra for his life's work. The atmosphere of the observatory was vibrant with new ideas and the promise of rapid developments. Hale had shown that strong magnetic fields occur in sunspots. The spectroheliograph was daily revealing new information concerning phenomena on the sun. The 60-foot tower telescope was completed, the 60-inch reflector was to go into service at the end of the year, and the new physics laboratory in Pasadena was to be occupied in May.

King was a pioneer in the study of thermal excitation of atomic spectra and in the classification of lines in the complicated spectra of metallic atoms. When Hale suggested to him the study of the effects of temperature on atomic spectra, the immediate objective was the interpretation of solar data. King's work did indeed supply invaluable information on the relative temperatures of sunspots and the normal solar disk. But it did more. It created a powerful means of analyzing atomic spectra and of assisting in the development of the quantum theory of the atom.

The electric furnace which he designed was set up in the new laboratory in 1908. A horizontal graphite tube containing the substance to be studied was heated to the desired temperature by a powerful electric current. Light from the vaporized material left one end of the tube to enter a spectrograph. Light from the other end of the tube went to an optical pyrometer, which determined the temperature. The visible and near-ultraviolet parts of the spectra of numerous elements were recorded, at temperatures of from 1600° to nearly 3000°K. On each spectrogram were also recorded arc spectra of the same substance that was used in the furnace. With painstaking attention to detail, King estimated the intensities of many thousands of lines on photographs of furnace and arc spectra. These data led to a classification of the lines of each element according to the temperature required for their appearance. Five main temperature classes made up the system, which was the forerunner of the present quantum classification.

In those early days it was well known that heated substances would produce continuous spectra, but some physicists doubted that heat alone would produce discrete emission lines. They thought that the emission of lines from King's furnace somehow depended on the fact that the carbon tube was electrically heated. Because the voltage was low (from 6 to 10 volts), King did not think that this was true, but, to make perfectly sure, he made other photographs of the emission lines, exposing the film only during intervals when the electric current was shut off. His observations steered thinking about spectra in the right direction and were later of tremendous importance in the sorting out of spectrum lines according to the quantum theory of atomic structure.

King engaged in other scientific activities that were of considerable importance. In his early years he investigated the Zeeman effect in lines of titanium, iron, and other metals. Later he studied spectra of meteorites. He was codiscoverer, with Raymond T. Birge of the University of California, of the isotope carbon-13, and he collaborated with R. F. Sanford of the Mount Wilson Observatory staff in studying carbon isotopes in N-type stars. During World War I he investigated phenomena of sound in water. After his retirement, in 1943, he worked for several years at the Pasadena office of the Naval Ordnance Test Station.

King had a delightfully gentle personality and was beloved by all who knew him. After months of illness he passed away at his home in Pasadena, on 25 April 1957.

Harold D. Babcock
Mount Wilson and *Palomar Observatories, Pasadena, California*