PRESIDENTIAL ADDRESS

BEATING THE RED QUEEN

or

?Quam celeriter vadimus?

PERCIVAL ROBERTSON
President, Illinois State Academy of Science

Those who have read the Wonderland adventures of Alice late enough in life to have really enjoyed them will recall that somewhere in that absurd land behind the looking glass this "Fancy's child" found herself in a garden that was divided into squares like a chess board. Here she met the Red Queen, who explained to her that although she was only a pawn at the time, Alice might become a queen at the eighth square.

> Just at this moment, somehow or other, they began to run . . . the Queen went so fast that it was all she could do to keep up with her: and still the Queen kept crying, "Faster! Faster!"
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> The most curious part of the thing was that the trees and other things around them never changed their places at all: however fast they went, they never seemed to pass anything . . . and still the Queen cried, "Faster! Faster!" and dragged her along . . . they seemed to skim through the air, hardly touching the ground . . . just as Alice was getting quite exhausted they stopped. . . . Alice looked round her in great surprise. "Why, I do believe we've been under this tree the whole time! Everything is just as it was!"
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> "Of course it is," said the Queen: "what would you have it?"
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> "Well, in *our* country," said Alice, still panting a little, "you'd generally get to somewhere else—if you ran fast for a long time as we've been doing."
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> "A slow sort of country!" said the Queen. "Now, here, you see, it takes all the running *you* can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!"

Usually Lewis Carroll appeals to scientists because behind all his nonsense one discovers the clear, scientific thought of the mathematician, Charles L. Dodgson. The question raised today is this: for all the break-neck pace brought about in considerable part by the application of science to our physical environment, are we as educators in science beating the Red Queen of material scientific progress, or do we, as did Alice, after all our strenuous endeavors, find ourselves under the same tree, with the voice of the Red Queen taunting, "If you want to get somewhere else, you must run at least twice as fast as that"?

For all whose Latin is as rusty as mine, *?Quam celeriter vadimus?* may be translated, *How fast are we going?*

The problem reduces to this: while scientific discoveries seem to be whirling us ever faster and faster, are we educators in science keeping our teaching ahead of the discoveries in natural science? There seems to be a tendency sometimes to infer that the function of science is merely to discover new facts. Some would add that it is the function of science to apply those discoveries. But scientific education has a more important task, and it will miss its greatest opportunity if it does not develop its potential ability to educate youth to live in the changing world that scientific discoveries are bringing about. It is a prodigious challenge.

It is not implied that it is the sole responsibility of scientific education to teach young people to adjust themselves to change in environment. All branches of education have their individual functions. But let us consider at the moment three opportunities of educators in science.

1. To teach the scientific factors connected with current events.
2. To develop better international understanding and, indirectly, better international cooperation through science.
3. To stress the importance of the scientific method and demonstrate its capabilities.

Science and Current Events

One simple and direct contribution practically all branches of science can make to education is to supply accurate and pertinent information regarding the scientific facts that lie behind current events. Failure to supply this information leads to the unfortunate view held by some students that the sciences are quite detached from ordinary human affairs. It seems to me we miss a valuable opportunity when we fail to supply scientific background for current events. A simple illustration will show how one science can contribute to such an understanding.

A beginning student in geology learns to recognize a few minerals and rocks; among these are the iron ore minerals and the sedimentary rock, coal. It does not detract from the basic purpose of geology, but makes the subject more vital to students, to discuss, though necessarily briefly, the distribution of iron ores and coal and their mutual effect on industrial developments, particularly in America and Europe, but also in critical parts of the Orient and elsewhere. Comprehension that England is having to use far thinner coal seams than we in the United States would consider using at the present time helps the student to understand that Britain's fuel problem is not based purely on the relative merits of private enterprise and government ownership, but on something more fundamental. The relative distribution of coal and iron in the Saar and Ruhr valleys and in the Lorraine hills provides a student with some comprehension of the fact that the Schuman Plan is not just a political maneuver, but that there are basic geological facts that lie back of the economic situation. These are very simple illustrations, but many elementary students are ignorant of the basic scientific facts mentioned, and they seem to have a feeling that coal problems in Britain, the Schuman Plan, and so forth, are purely political or economic questions.

Science and International Understanding

Possibly the most important single contribution that education can make to improve the present chaotic condition in the world is in teaching man to understand his brother man. If men all over the world understood more clearly why other peoples do things differently, we would be less likely to make the stupid mistakes we frequently make. We would know more clearly who real friends are, and we would be far less likely to offend as the result of misunderstanding. And scientific education can help us to understand our world neighbors.

A friendly article by Bruce Hutchison[1], in a recent popular periodical, gives a frank and kindly criticism of one of America's faults. He says, "That is the first trouble with you Yanks. You don't understand anybody. Not even your closest friend." He is too courteous to add, "Some of you don't seem to realize that there is any need of understanding anyone else."

Geography, that hybrid science resulting from the mating of physical and social science, is one of those subjects which has great opportunities to teach us to understand our neighbors abroad. It was my impression that the war had taught us that the American public needed to understand geography better, and I confidently looked for considerable upsurgence in that field, but any movement in that direction seems to have languished. Perhaps more is being done than I know—I believe more should be done.

This great country has quite unexpectedly found itself in the role of the leading nation in the world. If its citizens are to act intelligently in international affairs, they must understand why people act and think the way they do. Modern geography attempts to analyze physical environment and human response to that environment. Through this analysis one begins to comprehend why people live as they do. Many Americans seem to assume that if only other peoples would do as we do, their economic problems would be solved. Sometimes copying American methods might bring improved conditions; sometimes it would bring ruin. Only when we understand others can we explain America's aims to them in a way they will be able to comprehend.

Dr. Charles Malik,[2] Minister of the Republic of Lebanon to the United States, made some most enlightening statements regarding science recently.

> Asia has not sufficiently bothered to understand and control nature. The forces of nature remain, for the most part, mysterious and unknown . . . Now the mind, by the very act of piercing the structure and behavior of the material universe, places itself above that universe. But when the mind, for whatever reason, abdicates in advance this its birthright, namely the power to analyze, understand, control and utilize all natural phenomena, then it will tend to revere nature as something above it. There is more essential fear of nature throughout Asia than there ought to be, and one major task of the present phase of history is to liberate Asia completely from this fear. This can only be done by the intensive cultivation of science, and of that curious ancient Greek invention which we know today by the name of "theory". . . . Asia can attain power, dignity and abundance only if science and theory are enthroned at the heart of her intellectual life.

If only we can help our students to understand the real reason others behave differently from us, we can begin to develop in them a more tolerant view of others. And even more than tolerance, a word which sometimes, albeit incorrectly, seems to imply that one grants another the right to his opinion even if it is wrong, even more than this sort of tolerance, we need to and can develop in students a cultivated sym-

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[1] Hutchinson, Bruce, "The trouble with you Yanks is," *Saturday Evening Post*, December 9, 1950, Condensed in *Readers' Digest*, March, 1951.

[2] Malik, Charles, The problems of Asia, A speech delivered before the Political Committee of the General Assembly of the United Nations on December 11, 1950.

pathetic appreciation of the views and ways of others, and we can do it by appropriate use of scientific education.

Although the science of geography has great opportunities to teach international understanding, all fields of science provide opportunities. The very international nature of science, which recognizes of itself no national boundaries, can be used to illustrate the naturalness of international understanding, when placed on a proper basis.

Edmund W. Sinnot[3], in his address as retiring president of the American Association for the Advancement of Science, said, "Let us help develop the brotherhood of man through the brotherhood of science."

The Importance of the Scientific Method

But there is another phase of science teaching that to me seems more important than providing the scientific explanation of phenomena connected with current events. It is not more important than learning to understand our neighbors, but it is fundamental to that understanding. It is the teaching of science itself, not scientific subjects, but science—the scientific method of thinking.

John Dewey[4] once wrote:

> Science has been taught too much as an accumulation of ready-made material with which students are to be made familiar, not enough as a method of thinking, an attitude of mind, after the pattern of which mental habits are to be transformed . . . an effective method of inquiry into any subject matter.
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> Mankind so far has been ruled by things and by words, not by thoughts.
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> One of the only two articles that remain in my creed of life is that the future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind, and that the problem of problems in our education is therefore to discuss how to mature and make effective this scientific habit.
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> Scientific method is not just a method which has been found profitable to pursue in this or that abstruse subject. . . . It represents the only method of thinking that has proved fruitful in any subject.
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> Science has as yet had next to nothing to do with forming the social and moral ideals for the sake of which she is used. . . . when our schools truly become laboratories of knowledge-making . . . there will be no need to discuss the place of science in education.

When we consider that these challenging words were sounded by one of America's prominent educators forty years ago, and we look on the tremendous developments in the application of the scientific method to certain problems in the material sphere, we may appropriately ask, from an educational standpoint, Are we "beating the Red Queen" of material scientific progress? Is scientific education keeping ahead of scientific application? "How fast are we going?"

What is this powerful *scientific method?* A complete answer to that question is neither desirable nor possible at this point, but a few remarks may be appropriate. In the first place, science assumes that, even in the face of conflicting superficial evidence, there is fundamental discoverable order. When as the result of search, observation, controlled experiment, research, such order is discovered, it is called natural law because it is both natural and orderly.

But thoughtful man is never quite content to know that something is

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[3] Sinnot, Edmund W., Ten million scientists, *Science*, n.s., Vol. 111, p. 123, February 10, 1950.

[4] Dewey, John, Science as subject-matter and as method, *Science*, n.s., Vol. 31, p. 121, January 23, 1910.

so. He must know *why* it is so. The question "Why?" which is the youngster's touchstone to a comprehension of the world about him, which becomes a weapon with which he may at times confound both his parents and teachers, but which he learns, alas, may be turned against him by some cruel teachers and parents who demand to know *why* he did certain things; that same question, Why? does survive even the sometimes torturous experience of elementary education, and in the thoughts of some it becomes a dominant part of the scientific method.

The attempt to answer the question, Why? begins with speculations. Speculation over a problem leads to considering tentative or working hypotheses which may develop into broad theories or eventually into what James Conant calls "new conceptual schemes." These hypotheses and what grows out of them have to be checked constantly, and it is the habit of constant checking of tentative explanations that differentiates the true scientific thinker from others who may be brilliant thinkers but who are still not scientific thinkers. Those untrained in scientific thinking are likely to grasp a new idea and think of necessity it must be true, especially if it explains. To the scientist, explanation is insufficient; it must be right explanation. And there the difference lies.

Here is one of the places where it seems to me those engaged in teaching science have a real opportunity! If we can only inculcate in students the sense of the desirability and reliability of this method of thinking until they begin to use it naturally, they are not so likely to be misled by fallacious theories or doctrines. Marxism as practiced today is undoubtedly a theory designed to correct certain human wrongs, but it is not a right theory, as careful analysis shows.

How are scientific theories to be tested? This poses an interesting question, often answered, although it seems to me rarely answered adequately. The answer frequently given is that theories are tested and proved by demonstration. But we all know the frequent unreliability of human observations. They are subject to mistakes and misinterpretations, instances of which can be cited by any thoughtful scientist. Repeated demonstration is likely to be surer, but is not completely free from any of these snares.

Another answer to the question: How are theories checked or proved? is, By reason. This is a good answer, too. But reason, logical proof, is subject to fallacy, and although many fallacies can be easily detected, some are subtle and stubborn things, and any student of the history of science can point to fallacious explanations that were long accepted as true.

To me, a better answer to this question is: By *both* observation and reason. When these agree we can accept the explanation or theory with considerable surety.

Digression—A Problem Connected with Social Science

The scientific method has been very successful in dealing with problems concerned with inanimate things and extraordinarily precise mathematical statements of law have been discovered, but when the method has been applied to living organisms and more particularly to human problems as in the social sciences it has proved more difficult to discover precise mathematical formulae. Some, who have agreed with Kant's[5] reported definition, "Science in the highest sense of that word . . . is a knowledge of nature reduced to mathematical mechanism," have been critical of results that could not be reduced to such a form.

To such critics one might admonish patience. Some problems being studied by social scientists and others are most complex. I have been impressed with the fact that arrival at precise mathematical formulae takes time for repeated checking and refinement. Boyle discovered the relationship between gas volume and pressure in 1660. More than a century elapsed before Charles in 1787 and Gay Lussac, almost simultaneously, discovered that temperature has an effect on volume of gases, and combined this and the previous statements into what every freshman in chemistry and physics knows as the General Gas Law. But this law recognizes only two factors that produce changes in the volume of gas and they both are of relatively great order of magnitude. Although Bernoulli had presented a clear workable kinetic molecular theory of gases as early as 1738, it was 1873 before Van der Waal modified the Gas Law to include two other factors affecting the volume of a gas, factors that were clearly implied by the kinetic theory. It took over two centuries to develop a reasonably precise mathematical equation that included four important factors affecting gas volumes. This is the law that bears Van der Waal's name. The effects on gas volumes of these four factors have greatly differing orders of magnitude. I believe there have been approximately five significant refinements of Van der Waal's equation suggested in the past three-quarters of a century.

When we consider the time it has taken to derive a precise mathematical statement of law in a relatively simple situation, with only a few factors whose observable results were of considerably different orders of magnitude, we can afford to be patient with present approximate results in fields where the factors affecting the situations are numerous and apparently of similar order of magnitude. It is necessary to consider the effect of one or two important factors at first and then study the effects of others. As long as results are being checked against ever more carefully controlled experimentation and refined logical reasoning, we may confidently expect ever more precise and inclusive statements of law in fields where only approximations are found today. That the social scientists are well aware of their own difficulties was evidenced at the conference at Princeton a year ago.[6]

The Scientific Method Again

But there is another phase of the scientific method that should be considered. It may be desirable to pass it along to students in appropriate fashion. I referred previously to the seeking for the answer to the question, Why? It is a fundamental

[5] Little, Arthur Dehon, "Untilled field of chemistry," *Science,* n.s., Vol. 29, p. 719-23, May 7, 1909.

[6] "The natural sciences applied to social theory," *Science,* n.s., Vol. 111, p. 500, May 5, 1950.

assumption in science that there is a reason for things, and that that reason is discoverable if sought long enough with sufficient diligence. If the question, Do things necessarily have a reason or cause? has any validity at all, the answer must be left to the philosophers. The scientist never considers it so far as I am aware. He seeks cause, and as surely finds it.

We have all watched children stand a row of blocks on end and then send the whole row tumbling by striking the first block in the line; perhaps many of us have done it. What made the tenth block fall, that is, what was the immediate cause of its falling? Obviously the ninth block knocked it over. But we are not satisfied! What made the ninth block fall, and the eighth, and so to the first block? We say the child's hand struck the first block. We have traced a whole series of effects and causes, but we are not yet at a first cause. What made the child strike the first block? Was it because he was told to, and he responded obediently? Was it because of a desire to see what would happen, and he responded to curiosity? Or was it an accident? Or was it because of any one of several other possible reasons?

Here we have illustrated a conspicuous feature of the scientific method. Although we seek, and find, a whole series of related causes and results, ultimate cause seems to elude us. Some have gone so far as to say that ultimate cause is not within the province of science. It would be beside the point to discuss such a statement. It is sufficient to point out that ultimate cause escapes our present methods of study. But the scientific method certainly indicates that ultimately, step by step beyond immediate cause, stands ultimate cause. And when we recognize this fact we are impelled to write ULTIMATE CAUSE with capital letters.

Great numbers of natural scientists are inclined to agree with the truth of Lowell's familiar lines:

> And behind the dim unknown
> Standeth God within the shadow
> Keeping watch above His own.

Sir James Jean once wrote:[7]

> From the intrinsic evidence of his creation, the Great Architect of the Universe now begins to appear as a pure mathematician.

And, George T. Renner, well-known American geographer, said:[8]

> The Master Architect of the universe, the personification of morality, is Himself a superb geographer if we may judge from His handiwork.

From these and many similar quotations which could be cited, one might conclude that every man finds behind nature his own clearest concept of cause and calls it God. Perhaps it would be more correct to say that each finds as God that which he is most capable of recognizing as ultimate cause, and that Deity is neither the one nor the other, but the sum, the quintescence of all that humanity grasps as cause, is all this and infinitely more, as infinitely more as the universe exceeds human comprehension of it.

A very large number of thinkers, probably the majority of them, among those that could be classified as religious and those that could not, from the time of Aristotle to the present have come to the same conclusion as the unknown author of that great philosophic, poetical

[7] Jean, Sir James, *The mysterious universe,* New York, The Macmillan Co., 1932, p. 144.
[8] *Global geography,* Thomas Y. Crowell Co., New York, 1944.

drama, the book of Job. It will be recalled that after great calamities had fallen on Job, he had to endure the questionable comfort of three friends. After all this, Job is faced with stupendous questions voiced by the Almighty:[9]

> Where wast thou when I laid the foundations of the earth? . . .
> Who laid the measures thereof, if thou knowest? . . .
> Whereupon are the foundations thereof fastened? or who laid the cornerstone thereof;
> Canst thou bind the sweet influences of Pleiades or loose the bands of Orion?
> Canst thou bring forth Mazzaroth in his season? or canst thou guide Arcturus with his sons?
> Then Job answered the Lord, and said,
> I know that thou canst do every thing and that no thought can be withholden from thee.

Thinkers, scientific thinkers, basing their judgment on combined observation and reason have frequently come to the same conclusion.

One of the great scientists of our time, Charles P. Steinmetz, was once the house guest of Roger Babson. But let Mr. Babson himself recall the conversation:[10]

> Charles P. Steinmetz, who was unanimously recognized by the General Electric Company and other great similar organizations as the world's foremost electrical engineer, was once visiting my home. While talking over with him prospective future inventions, in connection with radio, aeronautics, power transmission, etc., I asked him: "What line of research will see the greatest development during the next fifty years?"
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> After careful thought, he replied:—"Mr. Babson, I think the greatest discoveries will be made along spiritual lines. History clearly teaches that spiritual forces have been the greatest power in the development of men and nations. Yet we have been playing with them merely, and have never seriously studied them as we have the physical forces. Some day people will learn that material things do not bring happiness, and are of little use in making men and women creative and powerful. Then the scientists of the world will turn their laboratories over to the study of God and Prayer, which as yet have hardly been scratched. When this day comes, the world will see more advancement in one generation than it has seen in the past four."

When those who have thoroughly studied and applied the scientific method come to conclusions such as these, we need have no hesitancy in indicating the nature of their mature judgment to young people who are looking for a practical guide to living. Lest I be misunderstood, I would agree with those who hold that the classroom is *not* an appropriate place to discuss religious doctrines. But these are not religious doctrines, and they do not come from men who are discussing religion. They are scientific conclusions arrived at by eminently competent students of the scientific method.

With the world so in need of some substantial foundation, can we fail to present to our young people in a serious, appropriate, and certainly scientific way such conclusions?

With the tremendous tempo of development of machines based on scientific discoveries are we, as educators in science, keeping pace? Are we "beating the Red Queen?" Are we keeping scientific education ahead of scientific application in the material world, or after a mad prolonged dash do we find ourselves under the same tree where we started? We certainly have great opportunities!

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[9] Job 38:4, 5, 31, 32; 42:1, 2.
[10] Roger W. Babson, *A business man's creed*, Fleming H. Revell Co.