Name: David McElhiney Date of Degree: May 25, 1958

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: MOTIVATING SCIENCE STUDENTS BY ACKNOWLEDGING THE UNCERTAINTY OF CERTAINTIES

Pages in study: 44 Candidate for Degree of Master of Science

Major Field: Natural Science

Scope of Study: In the days of Aristotle, science was considered to be nearly synonomous with philosophy; indeed the philosophers were the only ones who indulged in any form of science besides those who practiced the black art or some form of witchcraft. Then when science is said to have come into its own, science and philosophy drifted farther and farther apart, until they were considered to be entirely incompatible. We are now at the threshold of a new erra, as science and philosophy are drawing closer together again. We hear it said now that one cannot be a creative scientist unless he possesses a cultivated imagination; that those scientists who pursue observations and logic are constantly plagued by "facts" which they refuse to disregard. Materials for this study, were chosen primarily from journals and periodicals in which writers were concerned with the dilemma and inconsistancy in which scientists find themselves at times. Many of these ideas were accumulated from the many remarks of my colleagues and professors with whom this writer has discussed these problems.

Findings and Conclusions: It seems that very little of this new thought concerning the merging science and philosophy, has drifted into the classrooms of our elementary, junior high, and high schools. It would seem only natural that many of these students would like to know of this recapitulation taking place. Perhaps they could be motivated into some serious considerations of the definitions and the presumptions of science. They could very easily be thrilled to realize that science with all of its accomplishments could be considered to be in a dilemma. They could be mystified to the point of awe, when confronted with the suggestion that common sense is not the same as logic and that the latter is merely a matter of habit, education or communication. There are instances in all branches and at all levels of science when these uncertainties can be mentioned with good possibilities of motivation.

ADVISER'S APPROVAL James H. Zant

MOTIVATING SCIENCE STUDENTS BY ACKNOWLEDGING THE UNCERTAINTY OF CERTAINTIES

By

DAVID STANLEY MC ELHINEY

Bachelor of Science
Northwestern State College
Alva, Oklahoma
1949

Master of Education
Phillips University
Enid, Oklahoma
1954

Submitted to the faculty of the Graduate School of
the Oklahoma State University in partial
fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1958

MOTIVATING SCIENCE STUDENTS BY ACKNOWLEDGING

THE UNCERTAINTY OF CERTAINTIES

Report Approved:

Report Adviser

Dean of the Graduate School

PREFACE

Though this is by no means a unique observation with me, there are in all fields of science and mathematics, basic theories about which the experts disagree. In many situations, this disagreement is so pronounced that it seems as though there is no absolute truth, at least the line between truth and untruth is very wide and fuzzy. The greatest certainty we have is that we will always have uncertainties which is in itself somewhat reassuring to a student of science. It is my plan to develop an area of motivation that is very often forgotten or at least neglected. This attempt shall be directed primarily at the superior student who at times may feel that everything has already been discovered.

Indebtedness is acknowledged to Dr. James H. Zant, National Science Foundation Institute Director, for his assistance in this report; and to the staff in the library where many of the ideas in this paper were secured and developed.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
II.	SCIENTIFIC PHILOSOPHY	4
	Its Presumptions and Definitions	5
	Its Dilemma	11
	Its Communication	19
III.	UNCERTAINTIES IN LIFE	22
IV.	UNCERTAINTIES IN PHYSICS	28
V.	UNCERTAINTIES IN CHEMISTRY	34
VI.	UNCERTAINTIES IN MATHEMATICS	37
VII.	CONCLUSION	41
BIBLIOGRAPHY		43

CHAPTER I

INTRODUCTION

Though the problem today is not as great as it was a few years ago, there is a tendency on the part of many science and mathematics teachers to give their students the impression that they are living in a world of well established facts, the truth of which need never be questioned. These teachers, like our juvenile delinquents, can not be burdened with all the blame. Perhaps it is because of our American way of life, but very often anything in print is considered to be the truth. We are greatly indebted to our country and its forefathers, for the respect we can have for printed material, but in science where so much emphasis is placed on facts, the truth should not be considered lightly, expecially when truth itself is so abstract.

At any rate, the teacher may be the victim of "printitis" and leave the students with exactly the same impression as that created by the textbook. To some, this textbook impression is to be desired, and to those this problem is not real. However, it is to this same group that this discussion will be most applicable, and is therefore most directed.

This country has long been known for its mass production and its ability to apply almost any theory, but it has never been exceptionally known for its creativity. We are a country of Edisons, and can take an idea and make it practical. This aptitude for development is exceedingly commendable, and has made our nation the greatest the world has ever known, but just now the eyes of this world are looking to this country to "pull something out of the hat" so to speak. They have long ago been impressed with the number of our automobiles, television sets and automatic washers, but now they want a new theory of matter for example.

To promote this theory development, many of our large industries get their top scientists together for "pipe dream" sessions. In these meetings, the research men will listen to anything that anyone is capable of conceiving, from the educated calculations of their top engineers to the lay observations of the janitor, and fantastic schemes found in the suggestion box. They have little doubt as to their ability to build the project, if they can just get the idea.

So how do we produce creative scientists? This is our goal, our primary objective. Certainly a way not to produce them is to permit complacency and mass satisfaction to rule our classrooms. If our students constantly leave the classrooms with the feeling that documentary material is sufficient, if they are constantly reminded of what scientists do know with never an occasional hint at what they don't know, if textbook impressions are the only motivating device, the few creative scientists produced by this system will be produced in spite of the formal educational experience, and not because of it.

Much has been written condeming scientists for their own self-righteousness and conceit, and much has also been said about their humility. Many philosophers think that scientists must define the terms with which they work before they can proceed and still others defend the neglect of this practice as perfectly reasonable. Science teachers at all educational levels are becoming more and more aware of our increasing uncertainties but to this writer's knowledge, very little has been done with these uncertainties as a means of motivating a class or in particular the superior individual.

The purpose of this paper is to investigate several of these basic uncertainties as a means of motivation, thereby showing students that science is not a matter of cold hard facts, that have been previously digested. The method will be to separate science into several of its fields in which several uncertainties will be discussed in each section, and one section will contain considerable discussion on scientific philosophy in general.

CHAPTER II

SCIENTIFIC PHILOSOPHY

In the days of Aristotle, science was considered to be nearly the same thing as philosophy; indeed the philosophers were the only ones who indulged in any form of science besides those who practiced the "black art" or some form of witchcraft. Then when science is said to have come into its own, science and philosophy drifted farther and farther apart, until they were considered to be entirely incompatible. Philosophy still continued to dwell in abstractions but science, the "great science", delt only with truths and realities. We are now at the threshold of a new era, as science and philosophy are drawing closer and closer together again. We hear it said now that one cannot be a creative scientist unless he possesses a cultivated imagination, that those scientists who pursue observations and logic are constantly plagued by "facts" which they refuse to disregard.

Very little of this new thought has drifted into the classrooms of our elementary, junior high, and high schools, and it would only seem natural that many of these students would like to know of this recapitulation taking place, and perhaps they could be motivated into some serious considerations of the definitions and the presumptions of science. They could very easily be thrilled to realize that science with all of its accomplishments could be considered to be in a dilemma. They could be mystified to the point of awe, when confronted with the suggestion that common sense is not the same as logic and that the latter is merely a matter of habit, education or communication.

Its Presumptions and Definitions

When asked if there are any beliefs that are presupposed by science, the answer seems to be that such beliefs are not properly required for the carrying on of science, but that they are needed for its justification. This basic distinction between acting and justifying ones actions runs through the entire pattern of human behavior. One may act without at the moment being able to state the principle directing his actions, or he may enjoy a painting without at the time being able to give a good reason for the basis of his appreciation. Similarily one may pursue truth without being able either to define truth or to state what conditions must be satisfied by nature and by man if truth is to be obtained. In terms of our problem, this means that science may, for relatively long periods of time, go on its merry way, without requiring any examination of presuppositions or assumption; furthermore, science seems in general to be none the worse for this fact. In this sense there are no beliefs that are presupposed by science and the insistance on the part of certain philosophers that the scientists must uncover and make peace with his presuppositions seems somewhat misplaced. He can justifiably reply that science has been doing very well, thank you, without this kind of energy, and the prospects seems not too bad for the future.

This argument seems all very well but if left entirely alone, one might properly assume that nothing needs defining. Indeed there are those who advocate this method of education - that is, never to make a formal definition as such but by drill and use the definition becomes emplanted without the individual being aware of it. Certainly this would at times become very frustrating to the student, for if he were aware that he was taught in this manner he might reasonably say that no question need be answered on the spot. Rather, let us toy with it and perhaps its meaning will rub off, and suddenly we will all see the light.

Sir Isaac Newton was a God-fearing man, and a humble one. Ironically, the scientific revolution, which his discoveries initiated, gave birth to generations of proud theorists who were confident that they could solve everything in the universe by a rigid attention to the great scientific laws of Newton and his successors. The belief in the world as a "great machine," eminently knowable, was buttressed by the successive brilliant discoveries like Faraday's research into electricity, Darwin's theory of evolution and Mendeleev's periodic table of chemical elements. Down in the twentieth century, it made the average scientists seem rather uppity.

In the United States, especially, the dogma of science was widely enforced. "Science tells us" became the favorite lead-off of the billboard and the radio commercial. In universities as well as advertising agencies, the authority of scientists have an almost theological warrenty at a time when theology was frowned on. Small wonder that this sterotype of the domineering scientist became an object of some resentment by laymen.

The atom destroyed this idea of scientific omnipotence. The discoveries of atomic science forever toppled the confident certainty of the "great machine" viewpoint as surely as Newton and Copernicus ripped to shreds the physical science of Aristotle. It forced scientists to superimpose a whole new complex set of rules and observations on top of their old Newtonian physics, for Newton's laws did not apply to the peculiar movement of the atom world.

This idea of our scientific limitations has been very well expressed by one of the foremost scientists of our time, James Robert Oppenheimer. In an address entitled "Science and Common Understanding" he said in part:

> We are, of course, an ignorant lot. Even the best of us know how to do only a very few things well; and of what is available in knowledge of fact, whether of science or of history, only the smallest part is in any one man's knowing. The notion of universal knowledge has always been an illusion. We are not today tempted to search for keys that unlock the whole of human knowledge and of man's experience. - - And this is the mitigant of our ignorance ... although we are sure not to know everything and rather likely not to know very much, we can know anything that is known to man and may, with luck and sweat, even find out some things that have not before been know to him. This possibility is one of the manifestations of our belief in equality, that belief which could perhaps better be described as a commitment to unparalleled diversity and unevenness in the distribution of attainments, knowledge, talent, and power.[1]

The widespread conception of philosophy and science as radically independent fields of inquiry is of relatively recent origin. Less than two centuries ago, it was usually assumed that at least part of philosophy's task was to analyze the structure and assumptions of the sciences, and thereby to make explicit the nature of knowledge and of the pervasive features of the universe. The late divorce between philosophy and science was due to a number of factors, one being the influence of a powerful tradition. It was supposed, even by some of the great masters of science, that the proper objects of knowledge must be truths which are capable of being established with complete certainty. It gradually became apparent, however, that knowledge obtained by scientific methods does not conform to these specifications. It was not easy for most men to emancipate

---

[1]James Robert Oppenheimer, Science and Common Understanding" Newsweek, June 14, 1954, p 71

themselves from the old tradition; many were persuaded that what could not be achieved by science could be attained through philosophy. In short, the view became fashionable, especially in Germany, that philosophy had a privileged access to ultimate truth, and that it could achieve a more profound understanding of things by turning its back on science. Philosophy was thus reputed to be the exclusive quest for the eternal and the certain. Indeed, many philosophers acquired quite a contempt for painstaking logical analysis, and produced speculative systems of the world that possessed imaginative and emotional appeal but found little support in empirical inquiry. Philosophy also frequently served as a defense for the intellectual and social status quo.

The above arguments are acknowledged in a book by Hans Reichenbach, "The Rise of Scientific Philosophy." [2] The book is divided into two parts; the first is a critique of the assumption, that there are truths - that is, true propositions about the world which can be established by reason alone. The second and larger part of the book claims to show that with the help of modern tools of logical analysis, and when due heed is given to the findings and procedures of the empirical sciences, a number of outstanding issues in the theory of knowledge and the philosophy of nature can be definitely solved. Its author has, therefore, written a vigorous plea for an end to the unfortunate divorce of philosophy and science.

What can perhaps be safely said is that scientific philosophy finds no comprehensive plan controlling the operations of nature; that is, it

---

[2]Hans Reichenbach, The Rise of Scientific Philosophy, University of California Press, 1951

attacks problems in a piecemeal fashion and eschews all attempts at a wholesale solution of nature's secrets; and that its standard of reasoning and conpetent evidence are those which obtain in the varied empirical sciences.

Modern science aims at generality, and at the same time it seeks to provide dependable guides for the intellectual. But the actual evidence for its laws and theories is never complete and there is no guarantee that the guides will function successfully in the future.

So what theories should we believe? We must admit that theories must be made if there is ever any progress and that perhaps some of the terms in the theories need to be defined. Do we need to decide whether or not a theory has value before we accept it? If it is necessary to make a value decision to have a science before we can have one, then this decision is literally prescientific and has not, therefore, been shown to be any part of the procedures of science. Similarily, the decision that one problem is more worth-while as a focus of attention than another is an extra decision and forms no part of the procedures involved in dealing with the problem decided upon. Since it is these procedures that constitute the method science, the value judgment has not thus been shown to be involved in the scientific method as such. The perfect scientist does not allow this kind of value judgment to influence his work, just as a perfect father does not ask if his being a father has any value, nor a perfect lover does not ask if his loving has any value. For the same reason a so called perfect grouche does not ask if his griping has any value.

Among scientists it is taken for granted that a theory should be accepted if and only if it is "true." To be true means in this sense, to be in agreement with the observable facts that can be logically derived from the theory. Every influence of moral, religious, or political considerations upon the acceptance of a theory is regarded as "illegitimate" by the so-called "community of scientists." This view certainly has had a highly salutary effect upon the evolution of science as a human activity. It tells the truth - but not the whole truth. It has never happened that all the conclusions drawn from a theory have agreed with the observable facts. The scientific community has accepted theories only when a vast number of facts has been derived from few and simple principles.

If we restrict our attention to the two criterions that are called "agreement with observation" and "simplicity," we remain completely within the domain of activities that are cultivated and approved by the community of scientists. There is obviously no theory that agrees with all observations and no theory that has "perfect" simplicity. Therefore, in every individual case, one has to make a choice of a theory by a compromise between both criterions. However, when we try to specify the degree of simplicity in different theories, we soon notice that attempts of this kind lead us far beyond the limits of physical science.

In his latest book "What is Science?"[3] Mr. James R. Newman sets the volume's tone when he concludes that we must look to man and to science itself for a happy issue from the momentious problems which its progress has posed for mankind. He then goes from one essay to another which include a challenging assortment of facts and ideas, for example: Axioms, which troubled men so long because they were thought to be self-evident truths, are now recognized as nothing but assumptions. To be good, a

---

[3]James R. Newman, What is Science, University of Chicago Press, 1955

theory must be capable of disproof. It leads to new experiments and these, in turn, test the merit of the theory. The scientist works in two entirely distinct worlds - that of facts and that of interpretation and creative imagination. Scientists can profit by being more humble in the face of their immense ignorance, by a frank admission of awe and admiration for the great beauty of the things they study.

ITS DILEMMA

There is present in this country, symptoms of a growing distrust of science and scientists. The problem or dilemma is indicated by a number of phrases and statements (some only approximate quotations) which have appeared in speeches, articles, and books, particularly during recent months.

"Science is a conflict with society...Science has failed....Science is charged with some, if not most of the failures, violence, brutalities, suffering and confusion of our times....There is a growing anxiety to minimize and localize science....Science is tolerated only on its best behavior....It has become a passion and a luxury....A sacred cow....A cult of men in white coats....Its revelations have been considered alien to the human spirit....It will destroy civilization....There is a steady increase in irrationalism, unscientific and antiscientific attitudes of mind....Scientists are valuable but untrustworthy....There is a widespread tendency in the public mind to identify science with destruction.... Science must not be permitted to go on a rampage....Science is respected for its power; not for its spirit....Moral incompetency of science....A revulsion against science is said to be in the making....Disappointment and suspicion enshroud science....Hovering over science are storm clouds of suspicion, recrimination and fear....There is abundant evidence to indicate a serious decline in the popularity of science and scientists during the past few years....Scientists have been more pushed about by U.S. security regulations than any other group in our society....Touting for precious freedom, scientists are really speaking of permissive freedom - exemption from legal restraint in pursuit of knowledge....Let's demand a moratorium on science."

This is only a small sample of expressions which apparently reflect attitudes now in ascendance. The trend may be insignificant, transitory, or even imaginary; or it may be very real and serious. Irreparable damage may be done before it is apparent. Of course, critics of science have always been with us and science from its beginning has contended with these attitudes. The contemporary criticism, however, while exhibiting the same ignorance and lack of understanding, is arising in new and powerful quarters, is aimed at our basic philosophy, and appears to be building up to the point where the "sins of science" is a popular topic of conversation.

High school science students like to discuss such things as these - in fact, some of their most delightful experiences in the classroom come from what they thought was a complete abandonment from the lesson. They may even have felt that the class got clear away from the teacher when actually it could have and should have been under his direction all the time. Here is listed some of the causes of the adverse development in the field of science, each of which could easily be used for a topic of discussion in the classroom:

1. The concept that science and religion are in opposing camps -

suspicion that science is largely responsible for whatever degree of abandonment there has been of moral principles and ethical standards.

2. The internationalistic outlook of scientists - misunderstanding of the scientific philosophy of free exchange of information.

3. Social neutrality of science - the detachment and indifference of scientists to public attitudes - the practice that some scientists have of setting themselves apart, above, and beyond the rest of society.

4. The ridicule of areas of knowledge not subject to precise measurement, the disagreement among scientists themselves as to what can be git-itimately be considered "scientific."

5. The time lag between the views held by scientists and public awareness of such views.

6. Fear and resentment of the "destructive" power of science.

7. Disappointment in the wake of the exaggerated hopes penned by excited newspaper and magazine writers.

8. The extraordinary scientific illiteracy in America even among intelligent, educated people - ignorance of the basic precepts without which there would be no science at all.

The situation demands further study of causes and solutions. Science needs no special pleaders, but respect is a necessity and can come only with understanding. Scientists are dependent upon society for their privileges and it behoves them, no matter how many years it may take, to communicate a more accurate conception of science to as many people as possible.

Here it seems, lies something of value. We know full well that our entire class will not be creative scientists, and while we must do all that is humanly possible to motivate those who might possibly have superior ability, we must not create an aversion to science for the others. Though these slow learners need not climb the house tops to plead the cause of science, they need respect for science, which as stated can come only with understanding.

Many times scientists feel that they are surrounded with a public opinion by which scientists are described as secret sorcerers who, in closed laboratories, conjure up bigger and better methods of destruction. Everyone who has had any real contact with science or scientists knows well that this picture of science is highly misleading.

Sir Richard Gregory, the late editor of "Nature" said: "Science is one of the great human endeavours to be ranked with art and religion as the guide and expression of man's fearless quests for truth."

Dr. A. V. Hill, in an address entitled "The Ethical Dilemma of Science" defends this situation as follows:

> It is clearly our duty as citizens to see that science is used for the benefit of mankind. For of what use is science if man does not survive. It has been debated whether "the scientific mind" is fundamentally amoral. The real answer is that there is no such thing as the "scientific mind." Scientists, for the most part, are quite ordinary folks. In their particular scientific jobs, they have developed a habit of critical examination, but this does not save them from wishful thinking in ordinary affairs, or sometimes even from misrepresentation and falsehood when their emotions or prejudicies are strongly enough moved. Their minds are no more amoral than those of surgeons, lawyers, or scholars. As investigators, most of them realize that their function would be satisfied were they to introduce moral data into scientific argument. So scientific people, like all good citizens, must take account of ethical considerations and chief among these are integrity, courage, and good-will. Integrity forbids them to allow feelings of any kind to obscure facts, but that does not make them amoral. After all, integrity is the first condition of morality.[4]

---

[4]A. V. Hill, "The Ethical Dilemma of Science", Vital Speeches 18:617

Many times the student in the classroom may loose sight of the value of his texbook material. He may feel that it is so far removed from the things that are taking place in the world, that he is wasting his time learning basic science and answers to elementary questions. Perhaps he needs to consider briefly that industry is now, more than ever, luring and tempting the "pure" scientist. The change is part of the gradually emerging new pattern of American industrial technology. In the past, industrial researchers - as distinguished from long-hairs - concentrated on improving products. They worked by the rule book of existing knowledge; they were content if things happened, to be ignorant of the essential reason for the happening. Today, that is no longer enough. Technology has exhausted the existing canon of knowledge, both experimental and theoretical. From now on, pure science is needed to unlock the door to newer and better products.

There are several reasons why the elementary questions must be answered. Europe is petering out as a fountain of pure science. We no longer have the material for all our ideas. Most of all, the insights into natural phenomina, produced by pure science, have hatched the mechanical wonders of today. But scientists say these are mere indications of what can be done. Industrialists gleefully watch their Ph.D's pry away at the why of things, and excitedly wonder at the "gee-whiz" ideas that lie behind the doors their scientists will open.

There are those writers who have gone so far to express fear that physical science may not survive. This may seem very ridiculous in the light of all recent publicity, but there are some sensible points that can be mentioned.

Does the fact that we are said to live in the age of science mean that the method of physical science has penetrated into the thinking habits of the average citizen? Anyone who answers this in the affirmative must be prepared to explain many curious and highly publicized phenomina of very recent date, among them "dianetics," miscellaneous miracles," and the renewed controversy over dowsing, not to mention business as usual by the astrologers and the spiritualists.

There have been cranks in all ages, and in a free society there is certainly a place for them. They undoubtedly have a definite contribution to make to civilization: They amuse some people and stimulate others to useful ideas; occasionally they make money. Perhaps cranks should not be attacked as such, but what seems deplorable is that a very large segment of the educated public appears unable to distinguish a crank from a scientist. In spite of our vaunted educational system, it is all too clear that to most elements of the population, scientists are merely people who collect facts about all sorts of queer things and then use the facts to make all kinds of materials and gagets.

One of the characteristics of scientists and of other professional individuals for that matter, which most men in the street find exasperating, is the habit of maintaining a judicious balance about most questions under discussion, instead of coming right out with dogmatic emphasis and saying "This is so, and make no mistake about it." Of course if scientists were to take this positive attitude, they could be made to look like fools on so many counts that this same man in the street would loose complete faith in him; this is a worse fate than mere exasperation. At any rate, there is no question of the dilemma which also appears to be getting more complex.

Perhaps the most striking fact about modern science, in its explorations, ranging from the heart of the atom to frontiers of the universe, is that, like poetry, like philosophy, it reveals depths and mysteries beyond, and quite different from the ordinary matter-of-fact world we are used to. Science has given back to the universe that quality of inexhaustible richness and unexpectedness and wonder which at one time it seemed to have taken away.

We can claim science to be one of the most complex and far-ranging of our mental experiences. At any one moment we may have only a precarious hold on a temporary truth, and our consciousness of this ever urges us to seek fresh truths and new understandings. The pursuit of science presents to the human mind an enduring challenge on an endless frontier, quite apart from the material enrichment of mankind to which it may incidentally give rise. As Nobel Prize-winner, Sir Edward Appleton, Principal of the University of Edinburgh said, "If art for art's sake is a desirable slogan, why not science for science's sake?"

So despite the immense technological successes of science in our time, we must admit that there has been a widespread dissatisfaction. One has accused modern science for its emphasis on the material aspect of the world and for diverting the mind of modern man from human and spiritual interests. The humanities have developed almost segregated from the sciences. Philosophy, the key to the humanities, has become an isolated department, without much bearing upon the mind of present day scientists. An attempt has been made by many science groups for some improvement of this unsatisfactory situation by discussing in a strictly scientific way, possible bridges between the natural and the social sciences, between the sciences and the humanities. Such bridges cannot be built without some elements of common language and without a minimum of common philosophy.

One common problem discussed is "Reasons for the acceptance of scientific theories" because, in the solution of this problem, not only results of purely scientific research are involved, but equally considerations from the fields of social studies and the humanities, particularly from the philosophy of science. Some have stressed the point that in the physical sciences a general theory, such as the theory of relativity, is not accepted on the ground of mere agreement of its results with observed facts. The theory should also be simple, in agreement with common sense, with prevailing philosophies and should allow an interpretation of the universe that can be used to support a desirable way of life. Since none of these requests can be completely met by a theory, the actual acceptance has always been in effect, a compromise.

In this competition for the role of sense makers to a bewildered humanity, some feel that the scientists are loosing out. Not that people do not want to be instructed by science, they have never been more eager for whatever guidance it can give. People stand reverently before its theories, listening hard, trying most earnestly to understand. But what they hear is ever less intelligible. They have acquired a great deal of scientific information, more than laymen have ever before known, but they have at best, only a vanishing glimmer of an idea of what this information means.

Scientists themselves are hardly any better off. So far has scientific specilization gone that only the most selected can hope to understand the refinements of each specialist's work. Today there are few scholars who can call themselves mathematicians or physicists or biologists without restriction. A man may be a topologist or an acoustician or a coleopterist. He will be filled with the knowledge of his field, and will know all its literature, all its ramifications, but more frequently than not, he will regard the next subject as belonging to his colleague three doors down the corridor and will consider any interest in it on his own part as an unwarantable breach of privacy. The criteria for distinguishing sense from nonsense, have to a large extent been lost. Our minds are ready to tolerate any statement, no matter how ridiculous it obviously is, if only it comes from a man of repute. If this state of mind exists among men of science, what will be the state of mind of a public, taught to measure the value of an idea in terms of its incomprehensibility?

What then do we tell our students in our classrooms? Do we overlook this dilemma and stick to the absolute facts in the textbooks? Certainly that would be the easy way, but if this is the way we choose to take, out goes one of the possibilities for motivation. On the other hand, do we mention this dilemma at the start of each class? Do we constantly indicate that because there are a few points about which we are uncertain, that this is conclusive evidence that we must therefore be uncertain about all points? Obviously this would lead to mass frustration, and these discussions should be reserved for those rare times when by some sixth sense you realize an opportunity to thrill a student or a class.

Its Communication

Communication has become an irksome, two-pronged problem for the scientist. On the one hand, he finds it increasingly difficult to keep abreast of the work in his own and allied fields. On the other, he sees an ever-widening gulf separating him from the public. Expanding research programs yield data at an accelerating rate, yet the scientist's reading and retention rates are limited physiological and psychological factors.

A biochemist observed recently, "If I kept up with all the work being done in the narrow field of antibiotics alone, I would have no time left for research. As it is, I am buried under a mountain of papers, and reports."

Perhaps this problem of communication with the scientist and the public and within scientific groups, is also a problem with the science teacher. Certainly he is expected to keep up with developments in a very vast field, but if he cannot communicate, his cause is lost.

Fortunately, scientists realize the seriousness of this bottleneck, and undoubtedly it will be removed before it strangles scientific work. Scientific language, with its mathematical symbolism, is universal. Consequently, the problem is one of engineering. Once a method is set up by which information can be abstracted at various levels of complexity, recorded, cross-indexed in efficient research pathways, and made available in easily accessible form, the scientist will no longer need to flounder through unnecessary data to find what he needs. Increased reading efficiency will enable him to keep informed of developments.

But the problem of communication between the scientists and the public has no such obvious solution. The scientist is changing the world about us. His work is vital to our health, security, and prosperity. Yet to the average layman the work and the language of science are as mysterious as the witch doctor's "mumbo-jumbo" is to the savage. The pace of scientific discovery has left the layman far behind, and the few interpreters of science too frequently speak a language he does not understand.

In today's world, there is great popular respect for the scientist as a technician but there is great popular skepticism concerning the ability of the scientist in the areas of politics and social organization.

When one comes to international affairs, the scientist's deeply embedded sense of fraternity among those who seek knowledge in the same field of investigation, regardless of their nationality, is almost certain to expose him to the charge that he is "soft" in his thinking about the United States and other nations. This low appraisal of the scientist as a citizen is an important aspect of the anti-intellectualism that today appears all too commonly in the climate of public opinion. It has been encouraged and strengthened by conservative politicians and demagogues who say to the scientist, in effect: "Continue your research. Improve the machinery. Design new gadgets, and create more powerful weapons. But stick to your laboratories. We will determine how, and for what purpose, all these things shall be used in practical everyday life."

CHAPTER III

UNCERTAINTIES IN LIFE

Perhaps the most promising area for uncertainties continuing to be such, is that area in which life itself is a part. The poet and the philosopher have long been writing and talking about its mysteries, and it seems that when the scientist attempts to talk about life by way of definition, he is talking as a poet. We know, of course, that scientists know a vast amount of things about life - they know the conditions under which life can exist, or at least life as we know it, can exist. They can itemize these conditions in nice pretty order, and yet there is always some sneaky individual that does not fit. They have attempted to divide life into two kingdoms, the plant and animal. Yet, there is a group called the flagellates that seem to fit in both or perhaps neither. In nearly all these distinctions about which the experts have attempted to be precise, there is not a sharp clean line of division, but rather a broad fuzzy line.

The scientist cannot adequately define life or, at least, not as well as the poet. Aristotle, who we must call a scientist, perhaps gave some of the best definitions of these abstractions. He said an animal was an animal because of its animal soul, and a vegetable was such because of its vegetable soul. A man was therefore the highest because he possessed the most highly developed soul. Certainly no one could argue with this definition, but what exactly does it tell us? Our modern scientists can at least give us something more useful even though it might not be quite as truthful or philosophical.

With the failure of so many experimental efforts to find the secret of life, science was left in the half embarrassing position of having to postulate theories of living origins which it could not demonstrate. After having chided the theologist for his reliance on myth and miracle, science found itself in the unenviable position of having to create an mythology of its own; namely, the assumption that what, after long effort, could not be proved to take place today had, in truth, taken place in the primeval past.

The use of the term mythology is perhaps a little harsh. One does occasionally observe, however, a tendency for the beginning zoological textbook to take the unwary reader by a hop, skip, and jump from the little steaming pond or the beneficent chemical crucible of the sea, into the lower world of life with such sureness and rapidity that it is easy to assume that there is no mystery about this matter at all, or, if there is, it is a very little one.

This attitude has indeed been sharply criticized by the distinguished British biologist Woodger, who remarked some years ago: "Unstable organic compounds and chlorophyll corpuscles do not persist or come into existence in nature on their own account at the present day, and consequently it is necessary to postulate that conditions were once such that this did happen although and in spite of the fact that our knowledge of nature does not give us any warrent of making such a supposition." It is a simple dogmatism asserting that what you want to believe did in fact happen.

Yet today there are theories of all denominations that constantly plague us. We cannot of course completely disregard these theories for though our doubt may be justified, complete refusal to listen is not. Dr. George Wald of Harvard, firmly believes that if you start with a universe containing protons, neutrons, and electricity, life, that will pursue evolution, will eventually appear. There have been experiments that do suggest that perhaps a billion years or so ago, repeated bolts of lightning forced basic chemicals in the atmosphere into a coincidental merger. Simple substances were combined into more complex assemblages. Amino acids, proteins, and other biological building blocks were formed. Further experiments have led the biologists to conclude that the world's biological chain reactions could have started with volcanic eruptions: Lava, hitting the ocean at a propitious time in the earths geological evolution, could have heated sea water to temperature suitable for chemical blending. Sooner or later, Dr. Wald is sure life will begin on any planet like the earth (of which there are probably billions).

Many scientists think that life appeared on earth when the atmosphere, instead of being its present mixture of oxygen, nitrogen and carbon dioxide, contained methane, ammonia and hydrogen. These ingredients, still to be found in the atmospheres of Jupiter and Saturn, slowly combined into larger and larger organic molecules, according to the hypothesis. At last one molecule, a complex protein, showed the ability to absorb other molecules and create replicas of itself.

When Nobel Prize-winner, Harold Urey, elaborated on this theory last year, he said that one of his students was checking it experimentally. Graduate Student, Stanley L. Miller, 23, told how he had simulated conditions on a primitive earth and created out of its atmospheric gases several organic compounds that are close to proteins. Miller set up a closed apparatus containing water, methane, ammonia and hydrogen. When the water was heated, its vapor circulated the other gases past a small electric discharge, which promoted chemical reactions among their molecules. This sort of thing may have happened on the primitive earth, where lightning was probably common. In any case, the influence of the electric discharge was similar to that of the strong solar radiation beating down on the top of the primitive atmosphere.

When the apparatus of Miller's had run for a day, the water grew pinkish, and then turned red. After a week, Student Miller analyzed the mixture. It proved to contain at least three amino acids (glycine, alpha-alanine and bet-alanine). This was the hoped for payoff: Amino acids are the building blocks of which proteins are made.

Professor Urey and Student Miller do not believe they have created life. What they have done is to prove that complex organic compounds found in living matter can be formed by chemical reactions, out of the gases that were probably common in the earth's first atmosphere. If their apparatus had been as big as the ocean, and if it had worked for a million years instead of one week, it might have created something like the first living molecule.

From experiments such as these mentioned, most biologists believe that life developed in a this soup of organic compounds dissolved in an ancient sea. Today the seas contain no such stuff; if any is formed it is at once destroyed by living organisms. But in the days when there were no such organisms, molecules of sugar, proteins, etc., might have existed indefinitely, and where two of them came together they might join to form a large molecule. Eventually, so goes the theory, a larger complicated molecule was formed that could grow by absorbing neighboring molecules and could also reproduce itself.

Growth and reproduction are earmarks of life. But the biologists ask, did the seas before the beginning of life really contain organic compounds? If so, where did they come from? Scientists have dissolved a little ferrous sulphate and CO_2 in pure water enclosed in a specially designed glass cell and exposed it to high energy helium ion beams from a clyclotron. Analysis showed that a little of the CO_2 combined with water to produce formic acid and formaldehyde. Scientists have long known that solutions of formaldehyde sometimes turn into sugar.

There were no clyclotrons, of course, when the earth was young and lifeless, but the ocean probably contained CO_2 and a variety of other inorganic chemicals. High energy radiation from cosmic rays and other sources might have impregnated this virgin solution as it does today. It seems quite possible that it created formaldehyde. Then in a million years or so, this simple stuff may have turned into sugars, proteins and at last into living particles.

Then there are those who think life may have begun on earth as a mist of tiny organisms, or a "biological aerosol," high in the atmosphere, rather than in steamy primeval seas; Heinz Hager, of the U. S. Air Force Department of Space Medicine thinks life may exist today in that form on Venus, thought by many astronomers to be lifeless. Haber further thinks it possible that life attempts to gain a first foothold on planets within their atmospheres in the form of these biological aerosols. There, life becomes a major factor in the development of the chemical constitution of planetary atmospheres. As a consequence, the living matter alters gradually its chemical and thermal environment by changing the atmosphere's constitution, its absorptive qualities regarding solar energy, and its proper radiation, until life may finally succeed in developing explosively.

According to this concept, life does not depend entirely on the chances of the creation of a suitable environment effected through inorganic processes on the surface and within the atmosphere of a planet. Instead, life itself invades a planet and attempts to form an enrironment favorable for extensive development. In the light of this concept, Venus and Earth can be considered as presently being in different stages of development.

A mystery that has fascinated philosophers for thousands of years is how a complete organism develops out of a single fertilized egg cell. The biologists can disturb fertilized ova in all sorts of ways, but they cannot explain how the apparently simple cell can, all by itself, construct something as complicated as a whale or a man. A man's body starts as a single fertilized cell. Somewhere along the way it is arranged that certain of the cells arising from this common ancestor cell develop specialized characteristics and become nerve cells; certain others become liver cells, while still others develop into the cells of fingernails, hair, muscle, connective tissue, and so on. How does this specialization take place? Here, surely, is a deep problem which is at the very core of biological science.

CHAPTER IV

UNCERTAINTIES IN PHYSICS

What has happened to the relative tidy picture which we all had, not too many years ago, of a physical world built from only a couple of elementary particles? What sort of a delimma are we headed for, when the number of elementary particles now stands at perhaps twenty-five, and still tends to increase? Is it possible that these elementary particles have become neither elementary nor particles?

We have to admit that our conception of material reality today is more wavering and uncertain than it has been for a long time. We know a great many interesting details, and learn new ones every week. But to construct a clear easily comprehensible picture on which all physicists would agree is simply impossible. Physics stands at a grave crisis of ideas. However, the optimists among us look upon this view as a philosophical extravagance born of despair. We hope that the present fluctuations of thinking are only indications of an upheaval of old beliefs which in the end will lead to something better than the mess of formulas which today surrounds our subject.

In spite of our optomism, we must agree that the basic questions are giving the physicists trouble. Matter, for example, is common stuff, but the scientists do not know what matter is. The more they dig into the problem, the more confused they get. Dr. Erwin Schrodinger, Nobel Prize-winner in physics, points out that light can behave as waves and also as particles. So can electrons, protons and larger chunks of matter.

"A limited volume of gas, say helium," he admits, "can be thought of as either a collection of many helium atoms or as a matter of waves." By the same kinds of reasoning, a desk, a battleship, or even Dr. Schrodinger himself may be merely a fuss kicked up by conflicting waves. But Dr. Schrodinger is not sure of even this wild idea. He admits that neither he nor anyone else can answer the question. "What is matter?"

What holds the nucleus together? Electrical forces bind the electron to the atom, but they cause nuclear particles to fly apart. The powerful cohesion of protons and neutrons must be explained by a wholly different phenomenon. In the past quarter century, physicists have devoted a huge amount of experimentation and mental labor to this problem -- probably more man-hours than have been given to any other scientific question in the history of mankind. The problem is not only fundamental but alien to our experience. By all the laws of known forces, the particles in an atom's nucleus should flee from one another, instead of clinging together so strongly that we must build enormously energetic machines to pry them apart. The glue that holds the nucleus together must be a kind of force utterly different from any we yet know.

Dr. Hans A. Bethe, head theoretical physicist in the war-time atom-bomb project, is baffled by this force and says trying to explain the structure of atoms without understanding this mysterious binding force, is like figuring out the rules of a baseball game without seeing the ball. However, he has faint hopes for he thinks the binding force has something to do with mesons, and knowledge of the elusive particles is accumulating rapidly.

Where do cosmic rays come from? How do these particles attain their awesome energy? They have told us much about the nature of the nucleus, and they promise to tell more about the universe. The earth is under a ceaseless rain of particles from space. These cosmic rays, our only material contact with the vast universe outside our planetary system, have excited wonder and eager study ever since they were discovered forty-six years ago. They fall upon us with energies far beyond anything that can be produced on earth. They shatter the atoms of matter and make their nuclei explode into strange fragments. It is the investigation of cosmic rays that has been responsible for the discovery of so many new elementary particles in the past quarter-century. Besides this, cosmic rays are of great interest in biology, for by producing mutations in genes they are said to have played, and continue to play, a large role in the evolution of life on the earth. Thus, cosmic rays have been very useful to science, but the big question remains: Where do they come from, and how do they get their fantastic energy?

Professor Bruno Rossi of M.I.T., a leading authority on the subject, seems to favor, tentatively, the theory that the cosmic ray particles were shot out of stars at moderate speed and were gradually accelerated by magnetic fields in space. But he is by no means sure. "At present," he says, "no hypothesis about the origin of cosmic rays is unequivocally supported by theory of experiment."

Another great mystery of space is why the galaxies often look like spinning pinwheels. Cecilia H. Payne-Gaposchkin of Harvard Observatory has no ready answer. She points out that a great many galaxies including the earths, are spirals, but she does not know how they got that way. It may have something to do with the turbulence and viscosity of the thin gases between the stars, or with the magnetic fields that are supposed to permeate space. Astronomers believe that the explanation of the mysterious spirals will tell them much about the history of the universe.

Some of the uncertainties in physics have been exceptionally well discussed by Norman E. Nelson in an article written for the Yale Review entitled "Science and the Irresponsible Imagination:"

> Those of us who have not died are getting old, and what is more significant, these ideas of our flaming youth are getting on in years and ought to settle down and act their age. This in my opinion, they are not doing, and the popularizers still ride the magazine circuit, and in one field especially, I have noticed that the wiseacres are almost never challenged or heckled. In the space-time continuum that Professor Einstein rules as his domain, there are few indeed who dare to raise their heads and ask inquiringly about them.
>
> When I read the popularized physics of our present decade, I am compelled to recall the 'twenties' and my own uneasy bemusement which culminated when I read "The Nature of the Physical World." Therein, Eddington said, or seemed to say, that an iron bar is at one and the same time of different lengths according to the way its atoms are distributed by the magnetic field surrounding it, that magnetic field being determined not by where the bar is but by where it is observed from - the lonely platforms circling in space, each with a scientist peering through his telescope and jotting down his calculations. Since Eddington was acknowledged even by his grim fellow scientists to be the Lord Bishop of the physical universe, and since I was down by the effort to comprehend him, I succumbed to his style.
>
> Eddington was no mere popularizer and I do not visualize myself as reducing him to confusion in debate. My quarrel is with myself for believing what I did not understand, and as time goes on, with semi-scientific popularizers who disseminate what they clearly do not understand. Time should have brought a sifting of the first extravagant conjectures and a reassertion of the human right to examine what we are asked to believe. Time has brought no such thing. Because some awesome speculations have exploded convincingly in the middle of the Pacific, few of us are rash enough to quibble about anything bearing the label of the new physics.[1]

Mr. Nelson then continues at length concerning the literary liberties that are taken in science and mathematics. After quite a discourse on mathematics, he returns to physics.

> But the fun that the literary mystagogue has with arithmetic is nothing to what is possible when he begins taking liberties with the

[1]Norman E. Nelson, "Science and the Irresponsible Imagination" Yale Review, September 1954, pp 71-88

laws of physics. Perhaps the clearest illustration of this is the almost universal misunderstanding of the Heisenberg principle of indeterminacy. Like many great scientific discoveries, including Galileo's epical account of falling bodies and of missile trajectories, this principle is popularly mistaken to be the direct expression of experimental observation, but in fact it is a rational inference from an unobserved universal assumption to an unobservable universal conclusion. Heisenberg wanted to trace the path and note the speed of electrons moving within the atom. He found that the only way one can pin-point an electron for observation is by catching it in a beam of light of very shortest wave length, therefore of the very highest frequency, therefore, alas, of such violent force as to joggle the very electron one is trying to observe, altering both its speed and its direction. His conclusion, the Heisenberg principle, is that we shall never be able experimentally to find out precisely what the electrons are doing and will have to be content with a statistical estimate of probability as to their carryings-on. The presumption is unavoidable if unacknowledged that there is regularity if we could only detect it. Scientists have learned to operate with statistical probability since that is all they can get, but there is no reason why the universe has to conform to the limits of scientific information. Yet popular expositions of Einstein's universe and even articles in the "Scientific Monthly" explicitely assert the capricious irregularity of the universe on the authority of Heisenberg.[2]

The literary freedom referred to by Mr. Nelson might well be applied to authors of high school textbooks as well as the writers of articles in scientific journals. Mr. Nelson is obviously very upset by the way new theories are accepted and the same time, the old theories are still used, even though they are obsolete in the face of the new theory. He constantly selects parts of the theory of relativity upon which to prove his points.

Much as it may upset us, we cannot dismiss as mere bogey the disquieting results of the Michelson-Moreley experiment, which proved that a beam of light travels just as fast with, as it does against or across the earth's motion through space. This constancy of the speed of light is the firm foundation of all relativity theory, but it is a very upsetting constancy. If the speed of light is unaffected by the speed of the object it takes off from and by the speed of its recipient, the light is very constant indeed but everything else is bewilderingly inconstant. Although physicists do not attempt to explain why this is so, and have not yet shown how light defies the ground rules, nevertheless they have been able to obtain greater verifiable accuracy in their calculations

---

[2] Ibid

by using this theory than by rejecting it. Without pretending to resolve these perplexities I should like to reassure the man in the street and to mitigate the delicious vertigo of the literary relativist by remarking that neither the light-beam nor the earth are traveling at more than one speed whatever speed that may be. If they were, all bets and calculations would be off. The relativity is not in the speeds themselves but in the relationship between them - somehow.[3]

Then Mr. Nelson comments on the way scientific men write about the conditions of space travel and the many things which may be encountered if and when space travel is here.

Our imaginative friends are not content to be earth bound and let the light-rays do the moving about. They long to launch themselves in rockets whizzing so fast that their clocks and hearts will imperceptibly slow down, thus extending their youth and lives. I have no wish to dispute Einstein's theory on this point; I do, however, protest the careless rapture with which it is exploited in literary circles and not merely in limericks about the young lady who set out one day in a relative way and returned the previous night. On the authoity of Harvard scientists he assured us that two men, leaving the earth at the same instant in different rockets might return either one before the other, or (triumphantly) each before the other. Since the physicist sitting next to me made no protest beyond a subdued groan, the argument went unchallenged. How could anyone be certified insane, or sane for that matter in such a universe? We academics are so conscious of our historic role as enemies of new talent and new insights that we dare not challenge any folly that comes to us in the name of novelty. The irresponsibles have us buffaloed.[4]

---

[3]Ibid

[4]Ibid

CHAPTER V

UNCERTAINTIES IN CHEMISTRY

One could hardly point to a chapter heading in a chemistry text, without bringing up a great number of uncertainties. The very basis of inorganic chemistry, which we incidently consider to be basic of the entire chemistry field, includes an elaborate study of the atom and the molecule. Yet it is certain (if the word certain is permissible) that the oxygen atom looks no more like the way we draw it structurally, than the word "horse" looks like the animal for which it stands. It seems only fair to inform our students that all this time we spend learning the structural formula of atoms and molecules is not to get us acquainted with how they look. We know of course that they do have value in explaining reactions, the formations of compounds, etc.

Of course there are radicals on both sides of the argument. We can read articles now that there is no such things as "bonding" in the compounds, and that "ionization" is mere fantasy. The important thing it seems, for the student, is to recognize that these theories do work most of the time, that they are very useful, but at the same time they may be replaced. Dr. Hans Reichenbach, in his book "The Rise of Scientific Philosophy," is not concerned exclusively with the issues in the theory of knowledge and argues for the view that the laws of nature formulate merely statistical regularities and express only relations of "probability implication." Indeed he maintains that the notion of "strict causality" not only must be abandoned for subatomic processes but even for macroscopic events it is at best only an idealization or simplification of what actually occurs. Moreover since the "unobservable" constituents of subatomic physics and chemistry allegedly possess "causally anomalous" properties, he believes that the notion of "corporeal substance" is not adequate for describing physical reality in this sector of inquiry. On the otherhand, he claims that the familiar but not causal wave-particle interpretation of this reality can be avoided by adopting a new three-valued logic, which he says must admit "uncertainty" in addition to truth and falsity as a possible value for a statement.

Perhaps one area that this idea of uncertainty could be illustrated to the high school chemistry class, is in the discussion of catalysts. There are a lot of things we tell students about catalysts or catalytic agents. We say they do not initiate the reaction, yet there are isolated instances where they apparantly do. We say they do not enter into the reaction, yet in some highly controled organic reactions there was less catalyst at the end of the reaction than at the beginning. This story seems to indicate many qualities of the catalytic agent.

A certain Arab had three sons, who at his death wished to divide his 17 camels among his sons by giving half to the oldest, a third to the second oldest, and a nineth to the youngest. The situation seemed impossible until the oldest agreed to add a camel from his own herd to make the division possible without killing any camels. From the now 18 camels, the oldest received 9, the second 6, and the youngest 2, The oldest then took back his "catalytic agent" and everybody was happy.

There are areas in chemistry which we consider daily, that stop the experts from even developing much theory. Danish Biochemist Kaj

Ulrik Linderstrom-Lang pays his baffled respects to the proteins, of which all living objects are largely made. Living cells, even simple bacteria, make proteins by the dozens, but human chemists so far have not synthesized any. The proteins' molecules probably have long central chains of amino acids. These are coiled like springs, and all sorts of chemical oddments must be attached at precisely the right turns of spiraling chains. Progress thus far is not impressive, and until chemists have mastered the proteins' secrets, they cannot understand how much chemistry in life really works.

CHAPTER VI

UNCERTAINTIES IN MATHEMATICS

Modern mathematics has given us an entire raft of fantastic things about which we can talk and about which we can, for our purpose here list with the other uncertainties. We hear now that one plus one may equal one or any other thing we may want it to. We are told that a straight line may no longer be the shortest distance between two points. Our impression of these developments can probably best be expressed by Mr. Nelson again.

> If I am asked in the name of science or mathematics to accept these imaginative decors as sober accounts of the reality I live in, I have the usual right to self-protection and may sift the poetic statements for truth on my own responsibility. When for example, I am assured by my aesthetic acquaintances that a straight line is no longer, under Einstein, the shortest distance between two points, I have a right to ask them to point me out a shorter. The shortest distance between points on a spherical surface is the straight line through the circle, what ever the surface distance may be. The Riemann surface often used to clinch their argument turns out to be a mathematician's construct with a strictly theoretical barrier between the points. Still more frequently cited is the fact that light-rays, like everything else in a gravitational field, travel in a curve. But however sorry one may be for the light having to go around, it is difficult to see how that alters the distance between the points. Of course, if our literary minds confuse the unqualified with the negotiable distance they can make the universe out to be as queer as they like - and they do like.[1]

Of course many of the interesting things that occur in mathematics which confuse people and yet must be simple are age old. For example, we have been told in our youth, that if a person could cover half the distance across the room in one step and the remaining half in one step

---

[1]Norman E. Nelson, "Science and the Irresponsible Imagination" Yale Review, September 1954, pp 71-88

and so on, that he would never cross the room. Such arguments as these are discussed very beautifully by Mr. Nelson

When Zeno first pointed out the rift in the universe, life and thought were less complex. According to his teaching, a tortoise with a head start on Achilles would always maintain a slight or at least an infinitesimal lead, since he would always be covering some distance while Achilles was catching up to where he had just been. It took mathematicians almost two thousand years to catch up with Zeno and solve the problem by the differential calculus. But in the simple ancient days it was always comfortingly possible for anyone to pass a tortoise if there was one about. Today the man in the street must set out at fantastic speeds over unimaginable distances in several directions at once in order to detect whether there is or is not a discrepancy so slight that even a tax collector would disregard it. In such circumstances the man in the street prudently keeps his mouth shut and waits for the experts to give him the answer.

Dostoievske was, I believe, the first to announce with calm effrontery that whereas two plus two equals four is an interesting proposition, the proposition two plus two equals five is equally or even more so. These people have, however, received some apparent support from philosophers. Whitehead stuns the reader with this problem: One plus one equals two, but suppose they are drops of water. What then? The reader's sanity, reeling from this blow, may recover itself by reflecting on Whitehead's valuable distinction between the world of experience and the system of abstract symbols convenient for scientists. Of course two plus two makes four, though that does not explain fusion or fission any more than the multiplication table accounts for the propagation of the species.[2]

Dr. Reichenbach in his book "The Rise of Scientific Philosophy" devotes two chapters to the status of geometry, in which the belief that it is a system of truth that is shown. Geometry is a body of truth only as a branch of deductive mathematics, its asserted statements being then simply theorems of pure logic possessing no empirical content. On the other hand, geometry as a branch of physics is a set of contingent statements and can be asserted only on the basis of experimental evidence. Moreover, the statements of deductive geometry do not refer to anything in particular, and expressions like "line" and "congruent" must first be

---

[2] Ibid

interpreted in terms of physical configurations and processes before a geometric statement can be assumed to have factual content. Such interpretations are a species of definition; they are neither true nor false, but are decisions as to how language is to be used. Failure to recognize the need for such definitions in this or other branches of inquiry is still a potent sourch of belief in the synthetic truth.

The fact that mathematics is no longer the stronghold of intuition is very well discussed by Dr. Hans Hahn.

We have grown so accustomed to the revolutionary nature of modern science that any theory which affronts common sense is apt to be regarded today as half proved by that very fact. In the language of science and philosophy the word for common sense is intuition - it relates to that which is directly sensed or apprehended. Twentieth-century discoveries have dealt harshly with our intuitive beliefs about the physical world. The one area that is commonly supposed to remain a stronghold of intuition is mathematics. The Pythagorean theorem is still in pretty good shape; the self-evident truths of mathematics are in the main still true. Yet the fact is that even in mathematics intuition has been taking a beating. Cornered by paradoxes - logical contradictions - arising from old intuitive concepts, modern mathematicians have been forced to reform their thinking and to step out on the uncertain footing of radically new premises.

One of the outstanding events in the banishment of intuition from geometry was the discovery that, in apparent contradiction to what had previously been accepted as intuitively certain, there are curves that possess no tangent at any point, or what amounts to the same thing, that it is possible to imagine a point moving in such a manner that at no instant does it have a definite velocity. The questions involved here directly effect the foundations for the differential calculus as developed by Newton and Leibnitz.

Lest it be supposed that intuition fails only in the more complex branches of mathematics, I propose now to examine a failure in the elementary branches. At the very threshold of geometry lies the concept of the curve; everyone believes that he has an intuitively clear notion of what a curve is. We say that curves are geometric figures generated by the motion of a point yet it is not difficult to prove that this curve cannot be generated by the motion of a point, for no motion of a point is conceivable that would carry it through all the points of a wave curve in a finite time.

Repeatedly we have found that in geometric questions, even in very simple and elementary ones, intuition is a wholly unreliable guide. And it is of course impossible to adopt this discredited aid as the basis of a mathematical discipline. The same reaction occured when the theory that the earth is a sphere was advanced. The hypothesis was widely rejected on the grounds that the existence of the antipodes were contrary to intuition; however, we have got used to the conception and today it no longer occurs to anyone to pronounce it impossible because it conflicts with intuition. We can clearly see how concepts whose application is familiar to us acquire an intuitive status which is denied to those whose application is unfamiliar. The concept of "weight" is so much a part of common experience that almost everyone regards it an intuitive. The concept "moment of inertia," however, does not enter into most people's activities and is therefore not regarded by them as intuitive; yet among many experimental physicists and engineers, who constantly work with it, moment of inertia possesses an intuitive status equal to that generally accorded the concept of weight.

If the use of multidimensional and non-Euclidean geometries for the ordering of our experience continues to prove itself so that we become more and more accustomed to dealing with these logical constructs; if they penetrate into the curriculum of the schools; if we, so to speak, learn them at our mothers knee as we now learn three dimensional Euclidean geometry then it will no longer occur to anyone to say that these geometries are contrary to intuition. They will be considered as deserving of intuitive status as three dimensional Euclidean geometry is today. For it is not true, as Kant urges, that intuition is a pure means of knowledge. Rather it is force of habit rooted in psychological inertia.[3]

The arguments presented here by Mr. Hahn are much more conforting than those of Mr. Nelson, whose arguments border on the point of ridicule. Even though each argument may strike our fancy more at one time than at another, we must admit that each viewpoint seems to have value. For example, again giving it to the mathematician is Mr. Nelson:

If ever I am lured, quaking, aboard a space ship, it will be on the promise to take me, not just for a spin and back, but to the well-known point where parallel lines meet. I have grown so skeptical of that Ultima Thule that I should insist on reaching out from the porthole to touch the exact spot. Mathematicians have a way of talking about infinity as a limit as a straight line is the limit of circularity - just because such limits are, like the square root of minus one, convenient in their work. The mathematician as such doesn't care two pins whether actual lines actually meet or not.[4]

---

[3]Hans Hahn, "Geometry and Intuition" Scientific American, April 1954

[4]Norman E. Nelson, "Science and the Irresponsible Imagination" <u>Yale Review</u>, September 1954, pp 71-78

CHAPTER VII

CONCLUSION

There has been at attempt in the preceedings pages to develop an area of motivation. It is not impossible to imagine that these uncertainties could be overworked, so caution must be observed. Not that they resemble an explosive substance, but that presenting too many, too often, to the wrong group, could conceivable motivate in reverse. An attempt has been made to present both sides of the question. Because we cannot be certain about everything, and even though more of our old certitudes are disappearing, does not mean that we cannot be certain about anything. On the other hand, because we can be certain about some things does by no means imply that we shall very soon be certain about everything.

The whole of man's experience has demonstrated that the practical results required for tomorrow depend essentially on the "impractical" free curiosity of today. Perhaps everything does not require a scientific explanation. At the level of sophomore science, and almost universally at the level of general public discourse, one explains something by describing and analyzing it in terms of more familiar experience. This normally provides the illusion desired, for we seldom stop to think that the more familiar terms themselves require explanation. When one is talking at a fundamental level, however, explanation is a very different process. Familiarity ceases to be so useful, and the main requirement of an explanation, at this basic level, are compactness and generality. If you have a very compact way of stating relationships among a wide range of things and events, then you may say that you have explained them. The explanation need not be, and in fact almost surely is not, understandable in any ordinary sense. On the contrary, we must adjust ourselves to the notion that understandability, in this basic sense, is actually synonymous with conpactness and generality and that we cannot ask for more.

Is relativism dangerous for the masses of mankind? Would children be taught certitudes at the beginning and later taught to be uncertain? Or can they from the beginning be given the shifting answers of relativism? Limited absolutism has an answer. Show them that for some questions we have answers that are certain and for others we do not. The omission of an emphasis on the existence of some certitudes would result in two evils; a lack of exactness in knowledge and an absence of discipline and restraint in behavior, two evils which are not uncommon in the products of modern education.

Science reveals itself as a natural and integral part of man's whole life, an activity which at base, is a blend of logic, intuition, art and belief. It has been refined into an instrument of great beauty and precision by the few, but this science of the few is merely the distillation of the experience of the many. As a natural social activity of man, science belongs to all men.

BIBLIOGRAPHY

Benjamin, Cornelius A. "Science and Its Presumptions," Scientific Monthly, 73:150-3 September, 1951.

"Conference on the Validation of Scientific Theories," Science 119:233-4 February 19, 1954.

"Did Life Begin in Air, Not Sea?" Science Digest 32:42 August, 1952.

Eislley, Loren C. "The Secret of Life," Harper 207:64-8 October, 1954.

"Elegant Experiment" Time 63:60 January, 1954.

Frank, Phillip "The Variety of Reasons for the Acceptance of Scientific Theories" Scientific Monthly 79:139-45 September, 1954.

"Fundamental Questions in Science" Scientific American 189:47 September, 1953.

"Gene Now Obsolete Term" Science News Letter January 30, 1956.

Hahn, Hans "Geometry and Intuition" Scientific American 190:84-91 April, 1954

Hill, A.V. "The Ethical Dilemma of Science" Vital Speeches 18:617.

Hill, John W. & Payne, James E. "Scientists Can Talk to Layman," Science 117:403-5 April 17, 1953

"Humble Scientist, The" Newsweek 43:71 January 14, 1954.

Lindsay, R.B. "The Survival of Physical Science" Scientific Monthly 74:139-44 March, 1952.

Mather, Kirtley F. "The Scientist's Responsibility for the Interpretation of Concepts to Layman," Science 119:299-300 March 5, 1954.

Nelson, Norman E. "Science and the Irresponsible Imagination" Yale Review 43:71-88 September, 1953

"Origin of Life" Newsweek 49:42 January 7, 1957

"Origin of Photosynthesis" Science News Letter, 71:3 January 5, 1957

Price, Roger "How I Made A Remarkable Advance in the Field of Nuclear Fission," Colliers 131:65 April 11, 1953

Quimby, Freeman H. "Unpopular Science" Science 119:162-3 January 29 1954.

Reichenbach, Hans "The Rise of Scientific Philosophy" University of California Press, 1951 Scientific American 184:70-3 May, 1951.

Rudner, Richard "Remarks on Value Judgements in Scientific Validation" Scientific Monthly 79:151-2 September, 1954.

Schnidinger, E. "What is an Elementary Particle" Smithsonian Report 1950, pp 183-96.

"Semi-Creation," Time 61:82 May 25, 1953.

Smith, Lloyd A. "Number Wizzards Baffle Science" Science Digest 35:13-16 May, 1954.

Spigelman, Joseph H. "Can Science Make Sense" Harper 202:54-60 May,1951.

"Tooth Decay Theories" Science News Letter 63:196 March, 1953

"What was the Origin of Life on Earth?" Time 58:72 November 5, 1951.

VITA

David Stanley McElhiney

Candidate for the Degree of

Master of Science

Seminar Report: MOTIVATING SCIENCE STUDENTS BY ACKNOWLEDGING THE UNCERTAINTY OF CERTAINTIES

Major Field: Natural Science

Biographical:

Personal data: Born in Ashland, Kansas, August 3, 1926, the son of Percy Earl and Grace Curl McElhiney.

Education: Attended grade school in Rosston, Oklahoma; graduated from Rosston High School, Rosston, Oklahoma in 1943; received the Bachelor of Science degree from Northwestern State College, Alva, Oklahoma with a major in Chemistry in May, 1949, and the Master of Education degree from Phillips University, Enid, Oklahoma in May 1954.

Professional Experience: Entered the teaching profession after receiving the Bachelor of Science degree and have taught eight years since that time. All classroom experience has been in science or mathematics and in addition have served as an elementary principal, and two years as a high school principal; member Phi Delta Kappa, National Education Fraternity.