THE DEVELOPMENT AND EVALUATION OF HUMANISTICALLY-ORIENTED SCIENCE CURRICULUM MATERIALS

A Dissertation
for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY

Robert C. Morris

1974

This is to certify that the

thesis entitled

THE DEVELOPMENT AND EVALUATION
OF HUMANISTICALLY-ORIENTED
SCIENCE CURRICULUM MATERIALS

presented by

Robert C. Morris

has been accepted towards fulfillment
of the requirements for

Ph. D. degree in Education

William F. [signature]
Major professor

Date July 19, 1974

O-7639

ABSTRACT

THE DEVELOPMENT AND EVALUATION OF
HUMANISTICALLY-ORIENTED SCIENCE CURRICULUM MATERIALS

by Robert C. Morris

Originally, science courses on the high school level had been strongly influenced by a philosophy which emphasized the acquisition of a number of essential facts. This philosophy reigned supreme until the late 1950s when, following Russia's launching of Sputnik, the National Science Foundation's science curriculum projects emerged. The creators of these projects saw science as a process of discovery and sought to develop high school courses which presented science in this manner.

By the mid-1960s, a number of critics began to question the wisdom of the new courses. Many critics contended that the new courses presented science as a subject devoid of relationship to civilization, and thus failed to develop realization of the value of science.

The purpose of this study was to determine the relative effectiveness of humanistically-oriented secondary science curriculum materials which dealt with the same

laboratory activities as did the National Science Foundation sponsored Introductory Physical Science course. However, unlike the Introductory Physical Science course, which made little attempt to relate these activities to the course of civilization, the humanistically-oriented curriculum materials created as part of this study were designed to illustrate the value of these activities to civilization.

To access the relative effectiveness of these materials, a research instrument, the VOS Opinion Poll, was created. This instrument was designed to determine the relative value students attached to the laboratory activities which both the Introductory Physical course and the humanistically-oriented curriculum materials utilized in common. The VOS Opinion Poll was administered to the treatment group--five classes who subsequently received instruction in science using the humanistically-oriented curriculum materials--and to nineteen classes who were instructed in science using the Introductory Physical Science materials or the Chemical Education Study Materials. Following treatment, the VOS Opinion Poll was again administered to both groups.

Although prior to treatment the grand mean of the treatment and non-treatment groups had been comparable, following treatment, the grand mean of the treatment group exceeded that of the non-treatment group by 10.77, a figure which greatly surpassed the value required for significance at the .995 confidence level.

As a result of this study, the following conclusions were drawn:

(1) It is possible to bring about at least a temporary change in the relative value which students attach to specific laboratory activities through the use of curriculum materials which have been designed with this objective in mind.

(2) It is unlikely that exposure to scientific information of a technical nature or the performance of laboratory activities will, by themselves, cause most students to attach greater value to science.

(3) It may not be as difficult to bring about changes in attitudes and values as is generally thought.

This study could be instrumental in changing the long standing belief that when students attain factual knowledge that the formation of good attitudes and values will automatically follow. Further, this study questions the philosophy of the process-oriented science courses; namely, that what is taught is not as important as the method of instruction. This study suggests that value formation occurs most readily when carefully designed curriculum materials, whose major objective is to increase certain values, are employed.

THE DEVELOPMENT AND EVALUATION OF

HUMANISTICALLY-ORIENTED SCIENCE CURRICULUM MATERIALS

By

Robert C. Morris

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

College of Education

1974

ACKNOWLEDGMENTS

The writer would like to express his appreciation to those who provided so much valuable advice and assistance with this study: Dr. Lawrence R. Krupka, Dr. George R. Myers, Dr. Troy Stearns, and Dr. William J. Walsh, committee chairman, whose help and guidance far exceeded what could reasonably have been expected.

TABLE OF CONTENTS

	Page
Acknowledgments	ii
List of Tables	v
List of Figures	vii
List of Appendices	ix

Chapter

I.	The Nature of the Problem	1
	An Introduction to the Problem	1
	The Historical Background of the Problem . .	1
	A Description of a Typical Process-Oriented Science Course	16
	Proof That a Problem Exists	20
	Statement of the Problem	25
	The Hypothesis to be Tested	26
	Limitations of the Study	26
II.	A Review of the Literature Concerning the Problem	28
	An Overview of the Chapter	28
	A Survey of the Criticism of Existing Science Courses	29
	(1) The Process-Oriented Courses Have Not Increased Science Enrollments . .	29
	(2) Indications That the Process-Oriented Courses May Be Unable to Accomplish Their Major Objective . .	30
	(3) The Process-Oriented Science Courses May Have Been Designed with the Wrong Educational Aim in Mind . .	33
	(4) The Process-Oriented Courses May Neglect Educational Objectives Which Are of Most Value to the Future Non-Scientist.	36
	Suggestions for the Improvement of Science Curricula	38

Chapter | Page

The History of the Thrust Toward the Integration of Science and the Humanities . . 39
The Rationale for Science Courses Which Emphasize the Humanistic Aspect of Science 45
A Summary: The Philosophical Foundations of Courses Which Emphasize the Humanistic Aspect of Science 49
Developing Some Guidelines for Humanistically-Oriented Science Courses 50
The Humanistically-Oriented Science Curriculum Materials 52
Organization of the Thesis 53

III. Design of the Study 54

An Overview of Chapter III 54
Development of an Instrument 55
The Sample 58
Treatment 60
Evaluation Procedures 62
Analysis of the Data 63
Summary 63

IV. Analysis of Data 66

Data Collected - Pre-Test 66
Analysis of Pre-Test Data 67
Data Collected - Post-Test 69
Analysis of Post-Test Data 71
Further Considerations and Analyses 71
Summary 76

V. Summary and Conclusions 83

Summary 83
Conclusions 87
Discussion and Implications 87
Recommendations for Further Study 91
A Closing Note 92

Bibliography 93

Appendix A 99

Appendix B 103

Appendix C 109

LIST OF TABLES

Table		Page
1	Mean scores made by treatment and non-treatment groups on the VOS Opinion Poll prior to treatment	66
2	The grand mean of classes making up the treatment and non-treatment group	67
3	A comparison of the grand mean made on the VOS Opinion Poll by Science 9 classes and Introductory Physical Science classes prior to treatment	68
4	A comparison of the grand mean of chemistry classes in both treatment and non-treatment groups	69
5	Mean scores made by treatment and non-treatment groups on the VOS Opinion Poll following treatment	70
6	The grand mean of classes making up the treatment and non-treatment groups	71
7	A comparison of the grand mean of various classes in the treatment and non-treatment groups	73
8	A summary: Analysis of data collected . . .	79
9	The densities of some elements	152
10	The densities and melting point of several carboxylic acids	153
11	The spectral location or frequency at which certain groups of atoms will absorb light or radiant energy	161
12	Data illustrating the relationship between the freezing point of solutions and the molecular weight of the solute . . .	172

Table		Page
13	Some solvents and the freezing point lowering which they exhibit	175
14	The number of chemical bonds which some of the more common elements may form . . .	177

LIST OF FIGURES

Figure		Page
1	The life cycle of the mosquito Anopheles Aztecus	111
2	The life cycle of the malaria parasite Plasmodium Vivax	115
3	The worldwide distribution of malaria	118
4	The antennae of a variety of different kinds of mosquitoes	124
5	The chain of events which led to the death of hundreds of fish-eating western grebes . .	131
6	Some of the places of significance in the long history of the cinchona tree	136
7	The quinine molecule	138
8	The molecular structure of some of the compounds which have been used in the fight against malaria	142
9	A simple one-step separation	143
10	Using a separatory funnel	144
11	Solubility curves	145
12	A simple apparatus for the fractional distillation of a mixture of liquids	147
13	A distillation apparatus which provides a longer fractionating column than a simple test tube	148
14	Measuring the volume of a metallic sample . .	151
15	A melting point determination	153
16	One of the early experiments which led to the development of the spectroscope	156

Figure		Page
17	Wollaston's device for studying the spectrum	157
18	Wollaston's discovery of dark lines in the sun's spectrum	157
19	The bright line spectra of strontium, lithium and calcium	158
20	Kirchhoff's apparatus	159
21	The absorption spectrum of the compound 1-octene	160
22	A device for separating the molecular compound, water, into the gaseous elements hydrogen and oxygen	163
23	The mass spectrometer, a modern device for weighing individual atoms	164
24	An apparatus which can be used to determine the weight of carbon and hydrogen present in an unknown	166
25	Some of the ways in which five carbon atoms and twelve hydrogen atoms can be arranged	167
26	Laboratory apparatus for determining the freezing point of a solution	174
27	The chemist's representation of double and triple carbon-carbon bonds	178
28	Some carbon compounds which contain closed chains or rings of carbon atoms	179
29	Some of the chemical reactions which characterize the chemical family known as the alkenes	179
30	The structure of quinine	182
31	A "flow sheet" showing only a few of the thousands of known chemical reactions . . .	185
32	The molecular structure of quinine and plasmochin	190

LIST OF APPENDICES

Appendix		Page
A	The VOS Opinion Poll	99
B	Activities Employed with the Treatment Group	103
C	The Humanistically-Oriented Science Curriculum Materials Used to Instruct the Treatment Group	109

CHAPTER I

THE NATURE OF THE PROBLEM

An Introduction to the Problem

For as long as there have been schools, people have argued about just exactly what should be taught within these buildings. This study is concerned with one aspect of this age-old question; namely, the present need for improved curriculum materials for use in science classes at the upper middle-school level.

The Historical Background of the Problem

Historically, the establishment of universities and colleges preceded the high school as we know it today. When the number of American high schools began to increase in the years following the American Civil War, in many instances less rigorous versions of the college courses of the time were adopted as high school courses. For this reason, it is necessary to examine the philosophical basis of the earliest college science courses in order to determine the foundation of the high school prototype.

By the 13th century, many universities had been established, and at least one, the University of Paris, taught an impressive array of the sciences including astronomy, botany, physiology, zoology, chemistry and physics.[1] These courses were a curious mixture of fact and superstition; they included most of what could be called "scientific knowledge" at that time.

During these early years, some of the more important of Aristotle's books had been rediscovered; Thomas Aquinas sought to combine these works with Christian tradition. The result was a blend of reason with faith--as seen by authority--which tolerated no doubt or questioning by its adherents. This philosophy came to be known as Scholasticism. Crucial to a belief in Scholasticism was acceptance of a system of "absolutes" which were not dependent upon or relative to any external conditions. One educationally significant absolute took the form of the following syllogism: truth is an absolute good; knowledge is truth; hence knowledge is unchanging and good for all men and for all times.

Scholasticism utilized the teacher as a lecturer relaying knowledge; it called for the memorization of subject matter on a grand scale. Quite predictably, Thomas Aquinas looked upon science as an organized body of knowledge; he had little faith in the experimental method and most certainly did not see science as a process which could be used to gain control over nature. Aquinas divided

---

[1]Frederick Mayer, A History of Educational Thought, (Columbus, Ohio: Charles E. Merrill Books, Inc., 1966) pp. 157-158.

science into three distinct areas: physical, metaphysical and mathematical. He saw the metaphysical aspect as being of the most value, possibly because scientific procedures suffer the distinct limitation of being unable to answer the "important" questions since these fall in the realm of philosophy, an area not well suited to exact measurement and obvious, demonstrable conclusions.

One might wonder why Scholasticism became so widespread. A brief study of educational history would suggest that it owed much of its popularity to the fact that it was the official philosophy of the strongest religious organization in Europe. Thus, Scholasticism was furthered largely because it was endorsed by a powerful group which, by the thirteenth century, owned one-third of the land of Europe.[2]

From the thirteenth to the twentieth century, educational philosophy was strongly influenced by a Scholasticism which remained virtually unchanged. The fact that the situation was static was by intent, rather than accident. As Robert Hutchins, present spokesman for Scholasticism, puts it:

> But the function of a man as man is the same in every age and in every society, since it results from his nature as a man. The aim of an educational system is the same in every age and in every society where such a system can exist: it is to improve man as man.[3]

---

[2]Will Durant, The Story of Philosophy, (New York: Pocket Books, 1953) p. 104.

[3]Robert M. Hutchins, The Conflict in Education in a Democratic Society, (New York: Harper Brothers, 1953) p. 68.

Dr. Hutchins also provides more specific information as to how to go about the task mentioned. According to Hutchins, we are concerned with developing the intellectual powers of men. This can best be done if we study the most important subjects such as philosophy, history, literature and art; these subjects give us significant knowledge on the most significant issues.[4]

By the start of the twentieth century, socio-economic changes such as the mechanization of farming and industrial reformation made it possible for more students to attend high school than ever before. As a result, almost every decade since 1890 has seen a doubling of the total high school population.[5] Not only were the actual numbers changing, but the characteristics of the group were also changing. U.S. high schools now held the sons and daughters of the masses rather than only the children of the well-to-do. While the parents of the new high school student knew that education was good because those they envied valued it, they weren't quite sure how it was to be of value to their offspring. To the new student, the traditional education of the time represented a world with which they weren't familiar; they saw little relevancy to their lives in what they were learning, and their parents were unable to explain this paradox with any degree of success.

---

[4]Ibid., p. 71.

[5]U.S. Office of Education, Vitalizing Secondary Education, Bulletin 1951, No. 3 (Washington: U.S. Office of Education, 1951) pp. 1-5.

Against this background, another alternative to the choice between a Scholastic education and no education at all began to make its appearance. In the sixteenth century, Francis Bacon had written in praise of a "scientific method" which respected thought, even though this thought was different from established dogma, so long as such thought had basis in observation or experimental results. In Italy, Galileo had shown the advantage of such an attitude when he had proven that dissimilar weights fall at the same velocity using demonstration techniques rather than by pretentiously erudite argument.[6] This spirit would successively infuse itself in the writings of Locke, Hume, Mill and Spencer; it would reach educational culmination with John Dewey.

Dewey wrote of an educational philosophy which rejected static authoritarian dogma. He saw the student as an active learner taking part in a series of valuable experiences which began with the student's own interests and resulted in the development of a person who was interested in and able to solve the problems of the present. For the first time, how a student felt about something was equally as important as what he knew about it.

Dewey's philosophy has had a greater impact on social science courses than on science courses; perhaps the way to improve science courses was less clear. Generally, traditional science courses simply sought to justify their

---

[6]H. G. Wells, The Outline of History, (Garden City, N. Y.: Garden City Books, 1949) pp. 764-765.

existence in terms of the new aims advocated by Dewey. One national study carried out during 1941 disclosed that, while most science teachers professed to endorse Dewey's aims, most of these same teachers used teaching and testing procedures far more appropriate for the accomplishment of Scholastic aims.[7]

On Oct. 7, 1957, the Russians launched the first earth satellite, Sputnik; soon this event would focus national attention on U.S. education. Several weeks later, President Eisenhower made the American schools the official scapegoat, when, in connection with the problem of training scientists, he provided a comparison of U.S. and Russian schools which placed U.S. schools in a poor light. Said Eisenhower:

> This is National Education Week--it should be National Education Year. No matter how good your school is--and we have many excellent ones--I wish that every school board and every P.T.A. would this week and this year make one single project their special order of business: to scrutinize your school's curriculum and standards; then decide for yourselves whether they meet the stern demands of the era we are entering.[8]

President Eisenhower finished by repeating a description of Russian schools which had been furnished by the U.S. Office of Education; this description characterized Russian

---

[7]George W. Hunter and Leroy Spore, "The Objectives of Science in the Secondary Schools of the United States," No. 43: 633-647, School Science and Mathematics, Oct. 1943.

[8]U.S. News and World Report, Vol. XLIII, No. 21, Nov 22, 1957, p. 114.

schools as being very demanding. According to this report, Russian students spent more time in school than their U.S. counterpart, and most of them took five years of physics, four years of chemistry and 10 years of mathematics. This comparison placed U.S. schools in a very poor light, indeed. At that time, only about one U.S. student out of five took one year of physics; one out of three took chemistry, and advanced mathematics fared even more poorly.[9]

Unfortunately, this was either a poor analysis of the situation, or a misguided attempt to place the blame on someone else's shoulders. There is little doubt that the public schools--good or bad--were not responsible for our failure to be first in space; it was a clear cut hierarchy of priorities established by the government which had let the Russians enter space first. An investigation carried out by the U.S. Senate in November and December of 1957 revealed that the Russians had begun working very hard at the development of a missile system as soon as the war had ended. Further, it was evident that the U.S. administration had not been convinced that a space shot was worth the price. Major General John Medaris presented testimony before the investigating committee to the effect that at one point he had received specific orders _not_ to launch a satellite.[10]

---

[9]U.S. Office of Education, _Education in the U.S.S.R._, Bulletin 1957, Washington: U.S. Office of Education, No. 14, p. 67.

[10]_U.S. News and World Report_, Vol. LXXX, No. 26, Dec. 27, 1957, p. 64.

Clearly, our failure to be first in space was not in any way due to the shortcomings of the science curricula of American schools.

Somehow or other, the belated vindication of American schools provided by the Senate investigation failed to daunt the newly developed critics of education; it became a popular pastime to criticize American schools. Both Life and Look, two of the more widely read weekly publications, carried lengthy articles which compared U.S. and Russian schools. Look sought to compare what it called the soft, non-intellectual school day of a Chicago high school senior with that of a Russian student of like age.[11] Look pointed out the lighter load and greater status enjoyed by Russian teachers, but the general implication was that U.S. schools needed to "get down to business" if we were to be competitive with Russia.

Life's series on the "Crisis in Education" spanned a number of issues and probed the problem to a greater depth. The first of the series took the same approach that Look had, as Sloan Wilson wrote, "It's time to close our carnival." The central theme of this article was that the U.S. schools had "kowtowed to the mediocre" for too long a time.[12] The March 31st issue of Life told of the overwhelming load

---

[11] L. C. Derthick, "The Frightening Challenge of Russian Schools," Look, Vol. 22, No. 21, Oct. 14, 1957, p. 38.

[12] "Crisis in Education, Part I," Life, Vol. 44, No. 12, March 24, 1958, p. 35.

carried by an Oregon physics teacher, describing his classroom teaching, "moonlighting," and chaperon duties.[13] Subsequent issues dealt with the "Waste of Fine Minds,"[14] and "Tryouts for Good Ideas."[15]

By comparison, Life and Look were two of the milder critics. Exceedingly caustic critics included Arthur Bestor, who had previously written The Restoration of Learning,[16] and Rear Admiral Hyman Rickover, who, in Education for Freedom, made a plea for a national high school diploma. Said Rickover:

> If the local school continued to teach 'Life Adjustment' and 'How to know when you are really in love,' instead of trigonometry, French and physics, its diploma, for all the world to see, would be inferior.[17]

In referring to the U.S. Office of Education's 226 page report, Education in the U.S.S.R., Henry Hazlitt of Newsweek rubbed the ultimate salt in the wound when he wrote, "Wake up the Educators," an article which pointed out that the U.S. Office of Education in 1951 had endorsed the trend toward decreasing enrollments in algebra, geometry, physics

---

[13]"Crisis in Education, Part II," Life, Vol. 44, No. 13, March 31, 1958, p. 94.

[14]"Crisis in Education, Part III," Life, Vol. 44, No. 14, April 7, 1958, p. 89.

[15]"Crisis in Education, Part IV," Life, Vol. 44, No. 15, April 14, 1958, p. 122.

[16]Arthur Bestor, The Restoration of Learning, (N.Y.: Alfred A. Knopf, 1955, p. 111).

[17]Hyman G. Rickover, Education for Freedom, (N.Y.: E. P. Dutton and Co., Inc., 1959), p. 221.

and Latin. Hazlitt quoted the report as describing the trend in this manner:

> For the most part, the changes (diminishing enrollment in algebra, etc.) are in the direction of more functional education. They represent efforts to meet life needs of increasingly diverse bodies of pupils.[18]

Basically, the cry of most of the critics centered about increasing enrollments in home economics, shop, typing, business arithmetic and similar courses; in a similar vein, they decried the decreasing enrollments in traditional subjects such as foreign languages, mathematics and science.

In their evaluation of these critics, the public tended to forget that vocational course offerings such as home economics and industrial arts had been added to the curriculum as a result of public criticism to the effect that the schools were overly concerned with the preparation of all of their students for college.

Thus, in the confusion of the moment, a series of collosal misunderstandings, coupled with some highly vocal critics, allowed the blame for the U.S. failure to be first in space to be equated with supposed shortcomings in the science and math curricula of the American public schools. Fortunately, the abuse heaped on U.S. education was counterbalanced by some encouragement for improvement. With governmental help, school districts throughout the country set about to study and redesign their curricula in terms of

---

[18]Henry Hazlett, "Wake up the Educators," Newsweek, Vol. L, No. 22, Nov. 25, 1957, p. 111.

current and future expectations.

On the National level, one of the more significant developments was the passage of the National Defense Education Act in 1958. This bill made it possible for elementary and secondary schools to obtain federal grants or matching funds for the acquisition of equipment needed to strengthen instruction in science, mathematics, modern foreign language, history, civics, geography, and English.[19]

Through the National Science Foundation, a series of college institutes were established for the purpose of improving science instruction. Teachers fortunate enough to be selected to attend one of these institutes received $75 a week plus $15 for each dependent while attending school. Thousands of teachers took advantage of the chance to improve or upgrade their academic skills at Government expense.[20] Additionally, the National Science Foundation set about to encourage a reorganization of secondary school science programs. Teams of outstanding scientists and writers were assembled for the purpose of creating new, modern science courses. Later, institutes were established to ground science teachers in the new courses at public expense. From 1956 to 1967, the National Science Foundation contributed approximately $100,000,000 toward the

---

[19] Albert Piltz, "National Defense Education Act," Science and Children, Vol. 2, No. 7 (April, 1965) p. 9.

[20] Kenneth Brown and Ellsworth Oburn, Offerings and Enrollments in Science and Mathematics, Washington: Government Printing Office, 1957, p. 1.

support of major curriculum projects in mathematics and science.[21]

While Sputnik undoubtedly caused a tremendous acceleration in curriculum revision, many revisions had been started long before Sputnik was launched. For example, in 1951, work was begun by the University of Illinois Committee on School Mathematics.[22] Typical of the new curriculum projects was that of the Physical Science Study Committee. Started in 1956 with the support of the National Science Foundation, the Alfred P. Sloan Foundation and the Ford Foundation, this project involved several hundred people including college and high school physics teachers, artists, and equipment designers. Six hundred teachers were involved in the classroom trial of the materials.[23]

In 1961, a number of outstanding chemists and chemistry teachers gathered with the hope of repeating the success of the Physical Science Study Committee. This project was dubbed "The Chemical Bond Approach," and was ultimately published by McGraw-Hill and Co. However, Chemical Systems, the text produced by this committee, was to prove to be too difficult for the average student; as a

---

[21]Joe L. Evins, Hearings Before a Subcommittee of the Committee on Appropriations, House of Representatives, 89th Congress. Independent Offices-Appropriations for 1967. National Science Foundation. Document #6-473 (Washington: U.S. Government Printing Office, 1966) pp. 234-235.

[22]John I. Goodlad, Renata von Stoephasius and M. Francis Klein, The Changing School Curriculum (N.Y.: The Fund for the Advancement of Education, 1966), p. 11.

[23]Physics (Boston: D.C. Heath and Co., 1960).

typical example of its limited acceptance, by 1965, only 3% of the secondary schools in Minnesota were using this book.[24] A second project aimed at improving high school chemistry, the Chemical Education Materials Study, fared somewhat better, and by 1966, approximately 350,000 secondary students were using these materials.[25]

Other national projects followed. One study indicated that from 1960 to 1967, 90% of both urban and suburban school systems had made "significant" revisions in their science and mathematics curricula.[26]

Most of the new curriculum projects represented a significant departure from traditional materials. With their final product almost certain of publication, the committees working on these projects undoubtedly felt less bound to the long-prevailing doctrine of "essential facts" which had been implanted centuries earlier by Scholasticism.

Many of the new programs were influenced by psychologist Jerome Bruner who felt that one of the really unique contributions that instruction in science had to make to education centered upon application of scientific methods of thought to a wide assortment of problems. Bruner saw

---

[24]Robert Collins, "A Hard Look at Traditional Science," Minnesota Journal of Education, Vol. 45, April, 1965, p. 29.

[25]Goodland, von Stoephasius and Klein, op. cit., p. 47.

[26]Donald W. McCurdy, "Has the National Science Foundation Widened the Gaps in Science Education Among Urban, Suburban and Rural Schools?" Science Education, Vol. 52, No. 4, Oct., 1968, pp. 368-371.

science as a "process of discovery," in which the factual end of things became of secondary importance. Of prime importance, according to Bruner, was the development of a student who could think and reason.[27]

Although Bruner was one of the more recent spokesmen for an approach to science teaching which placed greater emphasis on the scientific method of solving problems, he was by no means the first to proclaim this as an important objective of science teaching. As John M. Mason put it in an unpublished doctoral dissertation written in 1951:

> In the past thirty years, leaders in the field of science education have continually called attention to the need and importance of emphasizing scientific methods and attitudes in teaching procedures. A review of the literature with respect to the objectives for science instruction substantiates this fact. Practically every major report since 1920 has either directly or indirectly indicated the value of science instruction for developing the attitudes and methods of science.[28]

Mason continued to build a firm case for his point by quoting over three dozen important committees and individuals, all of whom concurred concerning the necessity of developing the scientific method as an objective of science education. This belief stands in stark contrast with those who would place all of the emphasis on factual subject matter.

---

[27]Jerome S. Bruner, The Process of Education, (Cambridge: Harvard University Press, 1961).

[28]John M. Mason, "An Experimental Study in the Teaching of Scientific Thinking in Biological Science at the College Level," (Unpublished Doctoral Dissertation, Michigan State College of Agriculture and Applied Science, East Lansing, 1951) p. 1.

Some of the committees and authorities Mason quoted include: The Commission on the Reorganization of Secondary Education (1920); The National Society for the Study of Education (1932); The American Association for the Advancement of Science, Committee on the Place of Science in Education (1928); The Committee on Secondary School Science of the National Association for Research in Science Teaching (1938); The Progressive Education Association (1938); The National Committee on Science Teaching of the American Council of Science Teachers (1942); The Educational Policies Commission of the National Education Association (1944); The National Society for the Study of Education (1947); James B. Conant (1947); John Dewey (1934); Victor H. Noll (1939); Ira C. Davis (1942); and Earl James McGrath (1950). Mason concluded his argument by citing numerous other authorities to the effect that, at the time, little attention was being paid to the development of the scientific method as an objective of science teaching.[29]

During the early part of the 1960s, the science curriculum changes which had begun in the high schools crept down to the middle and elementary schools.[30] The new programs on these levels were even more strongly influenced by Bruner's philosophy, and they became even more process-oriented than their high school counterparts. As the designation implies, these courses had as a major objective,

---

[29] Ibid., pp. 1-18.

[30] Goodland, von Stoephasius and Klein, op. cit., p. 53.

development of the mental attitudes or thought processes which are characteristic of the process of science. These programs hoped to develop reserved judgment, critical thinking and the other intangibles which we usually associate with the process of science. In the following section, some of the characteristics of a typical process-oriented science course will be described in greater detail.

A Description of a Typical Process-Oriented Science Course

Representative of the process-oriented science courses is Introductory Physical Science.[31] An eighth or ninth grade science course which departs drastically from the traditional, Introductory Physical Science begins by asking:

> In what ways are things similar and what makes them similar?[32]

With this, and with other questions which it subsequently raises, Introductory Physical Science avoids providing a direct answer. Instead, it directs the student to a series of laboratory experiments from which the student is to draw his own answer.

The remainder of the text follows much the same pattern. It shows little concern for having the student memorize facts, or the results of experiments, but hopes instead to raise and answer questions such as:

---

[31] Introductory Physical Science, (Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1964).

[32] Ibid., p. 1.

> How can we compare amounts of solids, liquids and gases?[33]

Evidently, to the creators of the Introductory Physical Science program, acquisition of factual subject matter by the student is not of prime educational importance.

Not only does Introductory Physical Science minimize the memorization of factual information, but it also makes little attempt to point out the larger significance of the experimental work which the student performs. For example, in Chapter 2, the student carries out five experiments which are intended to prove that mass is conserved during physical and chemical changes. At the end of this task, the law of conservation of mass is formulated, and the limitations of the laws of nature are discussed, but no mention is made of the fact that this is one of the most important, far-reaching laws of nature. Indeed, the entire structure of chemistry has been erected on the foundation provided by the law of conservation of mass. Nor is this important point brought out in Chapter 6 when the law of constant proportions, which depends on the law of conservation of mass, is discussed.

If the Introductory Physical Science program tends to ignore the opportunity to develop student awareness of the significance of science to civilization, and also minimizes the acquisition of factual information, what objectives do the program deem important? A brief epilogue

---

[33] Ibid., p. 5.

presented at the end of the text attempts to clarify what objectives the student should have attained. According to this epilogue, the program has attempted to familiarize the student with some of the basic facts and ideas of physical science, the evidence for the facts, and the usefulness of the ideas. The epilogue also discusses some aspects of the process of science; it points to the inherent limitations of science due to the inaccuracy of measurement, and to the laws or generalizations which have been developed as a result of these measurements. The epilogue ends with a plea for the student taking care in accepting facts and generalizations in everyday life. The closing note asks:

> Do you ask for evidence to support what you read and hear? If your introduction to science has made you a more critical reader, a more careful observer, and a sharper thinker, your work during the year was worthwhile.[34]

To weigh the emphasis placed on the objectives as listed in the epilogue, it is necessary to review the treatment accorded them by the text. First of all, despite the claim that it attempts to familiarize the student with some of the basic facts and ideas of physical science, Introductory Physical Science makes little attempt to develop the facts and concepts of science other than those which play a part in the laboratory experiments presented. Further, because of the emphasis on laboratory development of nearly all the facts and concepts presented, less than approximately

---

[34] Ibid., p. 207.

one-half to one-third as many facts and concepts appear as would usually be presented in a traditional course. Plainly, the acquisition of facts is of secondary importance to the creators of the Introductory Physical Science program.

Only a very limited attempt is made to demonstrate the application of the facts and concepts which are developed. Any demonstration of the usefulness of the concepts which are developed, as claimed in the epilogue, must center about what the concept leads to strictly in terms of the experimental work performed. For example, the usefulness attached to the fact that mass is shown to be conserved in the several experiments performed is that it leads to the generalization that mass is always conserved in both physical and chemical changes. However, a use of greater significance--that this law is the foundation upon which modern chemistry has been erected--is not discussed. Again, as with the facts developed, the usefulness of concepts is limited to the contribution that they can make to the experimental program.

In fact, characteristic of Introductory Physical Science is the feature that, except in a very limited number of instances, it fails to discuss the application of the facts and concepts to any problem other than the experimental work at hand. The course work remains as pure science apparently completely divorced from the mainstream of civilization.

Since Introductory Physical Science has minimized the acquisition of factual subject matter and made only a very limited attempt to demonstrate the application of this subject matter, some other objective must claim the lion's share of its attention.

As indicated by the final statement in the epilogue, the major objective of the course is that of developing the mental attitudes or thought processes which are characteristic of the process of science; other objectives are relegated to a distant second place, and receive attention only in instances where they can offer support to the major objective.

Proof That a Problem Exists

By the mid-1960s, a number of critics began to question the wisdom of the new science courses. Since most of the criticism of these courses centered about the emphasis placed on the single objective previously described, rather than the technical competency of these courses, it is necessary to look briefly at the objectives of science education as set forth by authorities in the field.

Although many statements of the objectives of science teaching are to be found in the literature, for the present purposes, a summary of these objectives as provided by Dr. Eric M. Rogers, Associate Professor of Physics at Princeton University, will suffice.[35]

---

[35]Eric M. Rogers, "The Research Scientist Looks at the Purposes of Science Teaching," Rethinking Science Education, Fifty-ninth Yearbook of the National Society for the Study of Education, Part I. (Bloomington, Ill: Public School Publishing Co., 1960) p. 19.

According to Dr. Rogers, almost all of the objectives of science teaching which are usually proposed by most educators fall into one of the following three categories:

(1) Teaching facts and principles.

(2) Inculcating higher virtues such as those attitudes and thought processes which we might associate with problem solving.

(3) Developing an understanding and appreciation of science.

Most of the criticism directed to the process-oriented courses centered about the fact that they over emphasized objective number two--problem solving--to the near exclusion of objectives from the other two categories. In "An Odyssey Among the Projects," Ellsworth Tompkins describes his conviction that "something is missing" from many of the national curriculum projects. With reference to a new set of earth science materials, Tompkins says:

> . . . the erosive forces of Nature were portrayed very nicely in terms of cutting down mountains . . . but never in terms of ruining a cornfield.[36]

In the same article, Tompkins states that it seems to him that most of the new projects are more concerned with technical training in that they offer the subject in its pure, abstract form, devoid of application and

---

[36]Ellsworth Tompkins, "An Odyssey Among the Projects," NASSP Spotlight, No. 67, March-April, 1965, p. 1.

relationship to civilization. Tompkins asks:

> When every discipline has followed out its own internal logic, will the pieces make a pattern? . . . and will that pattern make a complete education?[37]

Tompkins goes on to say that a liberal education is more than a calculated dosage of technical instruction in a variety of subjects. Says Tompkins:

> The disciplines are essential, but a liberal education lies in their use for human purposes. They are powerful engines; but they stand useless if they are not hitched to the train of human affairs.[38]

He continues:

> . . . my protest is not against the over-valuation of the disciplines, but precisely against the undervaluation of their power in human life, when that power is consciously used.[39]

In addition to the omission which Tompkins describes, other critics question whether it is possible for the process-oriented courses to accomplish the single objective which they do emphasize. As pointed out earlier, most process-oriented courses hope to help the student learn to approach problems in the same way that a scientist would; they hope to help the student develop such higher virtues as critical thinking and reserved judgment. However, a number of educators question the possibility that those higher virtues which might be developed in a

---

[37]Ibid., p. 2.

[38]Ibid., p. 5.

[39]Ibid., p. 5.

science course will transfer, or carry-over, into other aspects of the student's life. To this point, Eric M. Rogers says:

> The attainment of higher virtues would, indeed, be wonderful. But science-teaching cannot confer these benefits on pupils unless the training given in science classes can somehow be transferred to other fields of study and to life in general. Is this transfer easily made?
>
> Early in the century experimental investigations by psychologists indicated that there is no transfer. Later studies showed that transfer can occur to some extent, but certainly not as easily as educators and the general public would believe.[40]

Dr. Rogers goes on to say that while the habit of careful weighing in physics will probably carry over to chemistry, it is less likely to carry over to weighing in the kitchen, and very unlikely to have further influence in areas less closely related.

D. P. Ausubel also echoes Rogers' criticism. Like Rogers, Ausubel doubts whether higher virtues such as using the scientific method will transfer across disciplinary lines. With regard to this lack of transfer, Ausubel says:

> This principle has been confirmed by countless studies and is illustrated by the laughable errors of logic and judgment committed by distinguished scientists who wander outside of their own disciplines.[41]

---

[40]Rogers, op. cit., p. 19.

[41]David P. Ausubel, "An Evaluation of the Conceptual Schemes Approach to Science Curriculum Development," Journal of Research in Science Teaching, Vol. III, (Issue 4) p. 258.

Ausubel also attacks another aspect of the process-oriented courses:

> The development of problem solving ability is, of course, a legitimate and significant educational objective in its own right. Hence, it is highly defensible to utilize a certain proportion of classroom time in developing appreciation of and facility in the use of scientific methods of inquiry and of other empirical, inductive and deductive problem-solving procedures. But this is a far cry from advocating that the enhancement of problem-solving ability is the major function of the school. The goals of the student and the goals of the scientist are not identical. Hence students cannot learn science effectively by enacting the role of junior scientists.[42]

Another objective commonly stated by the process-oriented courses is that of helping students to acquire an understanding of the nature of science. In recent years, however, several studies have been reported whose results seem to refute the claim that the process approach is better able to help students become acquainted with the nature of science. In "Understanding the Nature of Science: A Comparison of Scientists and Science Teachers," Merritt E. Kimball describes the result of a careful study in which the knowledge possessed by science majors, science teachers and philosophy majors concerning the nature of science is compared.[43] According to Kimball's study, philosophy majors show a significantly better understanding of the nature of

---

[42]*Ibid.*, p. 259.

[43]Merritt E. Kimball, "Understanding the Nature of Science: A Comparison of Scientists and Science Teachers," *The Journal of Research in Science Teaching*, Vol. 5, Issue 2 (1967-1968) p. 110.

science than do either science teachers or science majors. This raises the interesting question as to whether it is possible for students to obtain a good understanding of the nature of science simply by carrying on scientific experiments. Since philosophy majors seldom perform scientific experiments, yet apparently acquire this understanding to a greater degree than do science majors, perhaps the attainment of this objective does not necessitate use of the laboratory.

Serving to underscore the criticism of the process-oriented science courses was the sober fact that at least one study provided statistics which showed that, on a percentage basis, enrollment in all science courses on the high school level in one state had dropped about 7% from 1958 to 1967, a period of time closely corresponding to the rise of the process-oriented science courses.[44]

Statement of the Problem

From the preceding criticism, it seems obvious that both traditional and process-oriented science courses have certain deficiencies which make them less than completely acceptable to all educators.

The purpose of this study is to: (1) Develop secondary school science curriculum materials designed to illustrate

---

[44] V. A. Troxel and R. E. Yaeger, "The Science Curriculum Effects Enrollments in Science?" School Science and Mathematics, Volume LXVIII, No. 6 (June, 1968) p. 512.

the value of science, an objective which apparently is neglected by both process-oriented and traditional science curriculum materials; and, (2) To determine the effectiveness of these materials in the instruction of ninth, eleventh and twelfth grade high school students.

An instrument will be devised to determine the relative value which this group of students attaches to certain scientific activities as compared to the value placed on these activities by groups of students having taken traditional or process-oriented science courses.

The Hypothesis to be Tested

The hypothesis to be tested follows: Groups of students who are instructed in science using the humanistically-oriented curriculum materials devised as part of this study will place relatively greater value on certain specific scientific activities than do groups of students having taken certain process-oriented or traditional science courses which deal with the same scientific activities.

Limitations of the Study

Since only one school will be involved in the study, certain limitations must be accepted. For example, the study will be carried out in a suburban high school, so an attempt to extend the conclusions to an inner-city high school may not be wise. Similarly, no attempt will be made to determine whether the values formed persist over a long period of time, or whether they fade quickly; hence predictions as to long-term value formation will be of limited value.

CHAPTER II

A REVIEW OF THE LITERATURE CONCERNING THE PROBLEM

An Overview of the Chapter

In Chapter I of this thesis evidence was presented to the effect that modern science courses have not gained complete acceptance by all educators. The initial section of this chapter will probe more deeply into the criticism directed at these courses with the hope that such scrutiny will help provide guidelines for the curriculum materials to be designed as a later part of this study. This procedure is in accord with the feeling expressed by N. D. Anderson, Chairman of the National Science Teachers Curriculum Committee, that future efforts in curriculum reform should be based on a consideration of past efforts:

> Recent articles on science curricula often begin with an acknowledgment of the effort during the past decade to improve science teaching. This is appropriate when one considers the size of the human and financial effort that has been applied to the task. However, there appears to be agreement that, although many gains have been made, much also remains to be done. Our future efforts should be based on a thorough assessment of our past efforts and results.[1]

---

[1]Norman D. Anderson, "Curriculum in Science," The Science Teacher, Vol. 35, No. 8, Nov. 1968, p. 17.

The subsequent sections of this chapter will deal with the many suggestions for the improvement of science curricula with which the literature abounds. Finally, with due consideration given to the sources mentioned, a set of guidelines will be presented for the selection and development of science curriculum materials.

A Survey of the Criticism of Existing Science Courses

Much of the criticism of the process-oriented science courses centered about four closely related aspects of present courses:

(1) The failure of these courses to increase student enrollments in science.

(2) Indications that these courses might be unable to accomplish their major objective.

(3) The suspicion that these courses were designed with the wrong educational objectives in mind.

(4) The opinion that these courses neglect educational objectives which are of great importance to the average student.

We shall discuss the literary evidence for each of these points in detail in the sections which follow.

(1) The Process-Oriented Courses Have Not Increased Science Enrollments

Of this point, Fletcher G. Watson of Harvard's Graduate School of Education says:

> Since 1946 little effort has been given to the careful analysis and implementation of a science program appropriate for all pupils. Yet these are the pupils who fill our schools and who are faced daily by most teachers--- As is starkly clear in the urban schools and quite apparent elsewhere, the current science program has failed a large fraction of the pupils. They tell us so clearly by not electing science courses.[2]

In support of Watson's allegation was data which indicated that in the years since the first national science curriculum project--the physics course produced by the Physical Science Survey Committee--percentage enrollments in high school physics had decreased, while the nation's need for physicists had actually increased.[3]

While it would be unfair to hold the process-oriented science courses solely responsible for decreasing enrollments in science at the secondary level, they certainly must accept some of the responsibility for this trend.

(2) Indications That the Process-Oriented Courses May be Unable to Accomplish Their Major Objective

In connection with this possibility, Paul F. Brandwein questioned whether the process-oriented courses were carrying on experiments of the true inquiry type, as they purported to do. On the basis of over two hundred and

---

[2]Fletcher G. Watson, "Teaching Science to the Average Pupil," The Science Teacher, Vol. 34, No. 3, March, 1967, p. 25.

[3]"Physics Education Crisis," School and Society, Vol. 92, No. 2247, Oct. 17, 1964, p. 301.

fifty personal observations, Brandwein claimed that:

> In the vast majority of all cases (95-99%) the laboratory was carried on using laboratory materials which were prepared in advance so that a satisfactory conclusion would be reached at the end of that time--in the vast majority of schools, not one experiment was wholly planned or completed by high school students. True inquiry was not practiced.[4]

Brandwein cites several reasons why inquiry teaching isn't being carried on in the high schools: (1) school buildings lack the holding space to allow all experiments to remain set-up for more than one period; (2) the usual public school teacher's load is too heavy for carrying on inquiry teaching; (3) to lecture is easier; (4) examples set by colleges do not emphasize the art of investigation.[5]

Other teachers and researchers sought to investigate the effectiveness of the process-oriented science courses. J. E. Sherman probed the relative effectiveness of a different method of utilizing the laboratory activities called for in the process-oriented Introductory Physical Science course.[6] In this investigation, one group of students performed the usual laboratory activities in the customary manner, while a second, comparable group, never entered the

---

[4]Paul F. Brandwein, "Observations on Teaching: Overload and Methods of Intelligence," The Science Teacher, Vol. 36, No. 7, Feb. 1969, p. 38.

[5]*Ibid.*, pp. 38-40.

[6]Jack Eugene Sherman, "The Relative Effectiveness of Two Methods of Utilizing Laboratory-Type Activities in Teaching Physical Science," (unpublished Doctoral Thesis, The University of Wisconsin, Madison, Wisconsin, June, 1969) 209 pages.

laboratory. The second group viewed 2" x 2" colored slides showing the same laboratory activities that were being carried on by the control group. At the end of the semester, the Watson-Glaser Critical Thinking Appraisal, Form ZM, the Test on Understanding Science, Form JK, the Kuder General Interest Survey and the Introductory Physical Science Achievement Test, Chapters 1-3, were given to both groups. Sherman's conclusions: There were no significant differences in the two groups in critical thinking, understanding of science, knowledge of the Introductory Physical Science course or expressed interest in science.

In a related study, Oscar J. Brouillette compared the ability to carry on critical thinking as attained by students having had college science courses and those receiving no instruction in this field.[7] The Watson-Glaser Critical Thinking Appraisal, Forms X and W, was administered as both a pre- and post-test to both groups. Not only were no differences detected in the attainment of critical thinking on the part of the two groups, but Brouillette concluded that the ability to carry on critical thinking seemed not to be associated with those in any particular field. Further, Brouillette decided that the ability to sustain critical thought was not improved to a

---

[7]Oscar Jason Brouillette, "An Interdisciplinary Comparison of the Critical Thinking Objective Among Science and Non-Science Majors in Higher Education" (unpublished Doctoral Thesis, The University of Southern Mississippi, Hattiesburg, Mississippi, 1968) 128 pages.

greater extent by the natural sciences as compared to any other discipline. From his review of the literature, Brouillette also concluded that there was little evidence in support of the superiority of either process or content-centered biology courses. This same conclusion was also reached independently by another investigator, Richard T. Tanner, who contrasted the effectiveness of content and process-centered physical science courses.[8]

What implications may be drawn from the studies described? These studies strongly indicate that the process-centered courses may be unable to accomplish their major objective, that of developing the attitudes and thought processes which we ordinarily associate with the process of problem-solving. This is indeed a serious implication because the process-oriented science courses sacrifice many of the other important objectives of science teaching in order to emphasize the objective described. It may be that the process-oriented science courses not only are guilty of putting all of their eggs in one basket, but, in addition, the basket itself may be unsound.

(3) The Process-Oriented Science Courses May Have Been Designed with the Wrong Educational Aim in Mind

Other educators voiced the suspicion that the process-oriented courses were designed with the wrong

---

[8]Richard Thomas Tanner, "Expository-Deductive versus Discovery-Inductive Programming of Physical Science Principles," (unpublished Doctoral Thesis, Stanford University, Palo Alto, California, 1968) 183 pages.

educational objective in mind.

Claude Gatewood of the Educational Research Council of America wrote:

> In the main, the highly selective infusion by NSF of many millions of dollars into school science improvement, particularly at the secondary-school level, has resulted in the regeneration of a modern, up-to-date version of the elite science curriculum that existed during the latter part of the nineteenth century. Further, much of the excellent scientific material thus created is essentially irrelevant to the needs of a major portion of the students whom, according to both the philosophy and laws of our nation, it should now serve.[9]

Morris Kline, professor of mathematics at New York University, voiced quite similar feelings at the National Education Association Representative Assembly:

> What I am urging is a reform of science and mathematics education. I cannot condemn too strongly the curriculums of the past and am deeply saddened by the nature of current reforms.[10]

Later, Dr. Kline explained the basis for his feelings:

> But the reforms of science and mathematics education have made matters worse. The curriculums have been taken over by professionals whose aim, judged by the curriculums they have produced, is to train professionals. These reformers assume

---

[9]Claude Gatewood, "The Science Curriculum Viewed Nationally," The Science Teacher, Vol. 35, No. 8, Nov. 1968, p. 19.

[10]Morris Kline, "The Liberal Educational Values of Mathematics, Science and Technology for Youth," National Education Association, Addresses and Proceedings (Washington, D.C., 1965) National Education Association of the United States, Washington, D.C., pp. 50-67.

> that mathematics and science are ends in themselves, that students are automatically motivated, and that the goal is to rush education so that 17-year-olds can start writing research papers.[11]

It is worth noting that over fifty years earlier, in 1916, John Dewey had made essentially the same criticism of the science courses of that decade. After pointing out the fact that most of the pupils were not going to become scientific specialists, Dewey went on to say that traditional science courses were too concerned with imparting scientific information as an end in itself; the result was that the connections between the information and everyday living were hidden; all that the student actually accomplished was to acquire a technical body of information and a peculiar vocabulary.[12]

It is also worthwhile to speculate concerning Dewey's feelings about the laboratory activities of the process-oriented courses. These laboratory activities are definitely concerned with what Dewey called "the problems of science." Regarding laboratory work of this sort, Dewey maintained that while contact with laboratories represented an improvement over learning science out of a textbook, all too frequently the problems pursued were the "problems of science," and as such, students failed to see the applications

---

[11] Ibid., p. 65.

[12] John Dewey, Democracy in Education, (New York: The Free Press, 1916) pp. 220-240.

and relationship of these problems to life.[13]

(4) The Process-Oriented Courses May Neglect Educational Objectives Which Are of Most Value to the Future Non-Scientist

Closely related to the accusation that the process-oriented science courses were overly concerned with the technical training of future scientists was the belief that these courses neglected educational objectives of science teaching which were of greatest importance to the future non-scientist.

Speaking to this point, Milton O. Pella of the University of Wisconsin described the nature of the neglected objective:

> It is obvious that a society that has evolved to its present level due to science and that will continue to develop only with more science must be literate in science. This opinion has been expressed by many scientists, philosophers, historians, sociologists and educators.[14]

Later, Pella clarifies what he means by the phrase, "literate in science," when he explains that the scientifically literate person is one who understands the interrelationships between science and society. Furthermore, says Pella, the scientifically literate person understands that the social consequences of science come about as a

---

[13]John Dewey, Lectures in the Philosophy of Education: 1899, (New York: Random House, 1966) pp. 288-294.

[14]Milton O. Pella, "Scientific Literacy and the H. S. Curriculum," School Science and Mathematics, Vol. LXVII, No. 4, Whole 591, April 1967, p. 346.

result of the interaction of science and society.[15]

Another prominent educator, Morris Kline, also endorses much the same objective advocated by Pella. Kline suggests that science teachers should teach the "broader cultural values of science." Says Kline:

> Not to teach the larger cultural significance of science while teaching science is like asking students to swallow food but not letting them digest it.[16]

Further on in the same address, Kline amplifies his statement:

> Knowledge is a whole. Life is not segregated into mathematics, physics, chemistry, and so forth and into distinct values which these subjects offer. If our subjects have cultural values we cannot omit them and trust that either the student will see them himself or will ultimately in some unspecified way fit them into the picture. We cannot present him with some pieces of a jigsaw puzzle and trust that the pieces will some day and somewhere be handed to him and that he will fit them into the proper place.[17]

The preceding section is a representative survey of the criticism directed toward the process-oriented courses. It is now appropriate to center attention on those educators who suggest that science teaching must take a new direction if it is to be relevant to all students.

---

[15] Ibid.

[16] Kline, op. cit., p. 64.

[17] Ibid.

Suggestions For the Improvement of Science Curricula

The most concrete suggestions for the improvement of science curricula initially took the form of new courses. In England, the Nuffield Foundation Science Teaching Project sought to develop a science course which, hopefully, would prove to hold greater significance for the average student. Of the Nuffield project, the coordinator Kevin W. Keohane, wrote:

> If any course of study is to be successful for them (the average student), it is most necessary that there should be a cohesion and pattern running through the entire teaching and aimed particularly at realizing in the children a significance in the science they have learned. "Significance" has been taken as the cornerstone of our philosophy, and on its achievement will depend the success of the work.[18]

Examination of the Nuffield materials indicate that they place greater emphasis on the integration of the sciences with each other than they do on the integration of the sciences and humanities.

Equally concerned with the significance of science, the University of Iowa Science and Culture Project (ISCP) sought to develop a science course which placed greater emphasis on the cultural interactions of science.[19] This project utilized specific examples of the way in which

---

[18]Kevin W. Keohane, "Toward an Integrated Teaching of the Sciences," The Science Teacher, (Oct. 1968) p. 41.

[19]J. Doyle Casteel and Robert Yager, "The University of Iowa Science and Culture Project," School Science and Mathematics, Vol. LXVI, No. 9, Part II of II, Whole 587, (May, 1968) pp. 412-415.

science and scientists influence, and are influenced by, the culture in which they live.

Individual school systems also saw a need for the improvement of science curricula. In June of 1964, David E. Newton reported concerning a course which was somewhat similar to the University of Iowa project.[20] Developed by the teachers at Ottawa Hills High School in Grand Rapids, Michigan, this course sought to describe the nature of science, to show how science has developed, and to illustrate its impact on our culture.

Both the Ottawa Hills project and the University of Iowa project were unique in that they were among the first projects to attempt the integration of science and the humanities.

The History of the Thrust Toward the Integration of Science and the Humanities

As early as 1920, various individuals and certain groups had protested the fact that science courses had paid little attention to the relevancy of their subject matter. For example, in 1920, the Science Committee of the Commission on Reorganization of Secondary Education suggested that science education concern itself with things more closely related to human activities rather than being overly concerned with subject matter which

---

[20]David E. Newton, "The Role of Science in General High School Education," School Science and Mathematics, Vol. LXIV, No. 6, Whole 566 (June 1946) pp. 550-552.

seemed unrelated to the student's experience.[21]

Throughout the 1930s and early 1940s, science educators responded to these suggestions by incorporating such topics as "Our Water Supply" and "How Do Automobile Engines Operate?" into the upper middle school science texts. While the treatment of these topics did not do much to illustrate the interrelationships of science and civilization, these topics were more relevant to the everyday life of the student than many of the topics covered by certain present process-oriented courses.

In 1945, the Harvard Report on General Education repeated the suggestion that science be integrated with the humanities:

> . . . Science instruction in general education should be characterized mainly by broad integrative elements--the comparison of scientific with other modes of thought, the comparison and contrast of the individual sciences with one another, the relations of science with its own past and with general human history, and of science with the problems of human society . . . .[22]

One year later, the National Society for the Study of Education echoed this suggestion, pointing out that developments produced by science have had an impact on

---

[21]Commission on Reorganization of Secondary Education, Reorganization of Science in Secondary Schools. U.S. Bureau of Education Bulletin, No. 26. Washington: Government Printing Office, 1920, p. 62.

[22]General Education in a Free Society. Cambridge: Harvard University Press, 1945, p. 267.

man's thought as well as on his way of life.[23]

In 1960, the National Society for the Study of Education again stressed this same theme when it devoted the first chapter of its Fifty-ninth Yearbook to a consideration of the significance of science to our civilization.[24]

These suggestions were the first part of a gathering wave which was to reach much greater proportions by the late 1960s. In 1968, the theme of the National Science Teachers Convention was "Science in the New Humanism." The speakers, and their topics follow:

> Jacob Bronowski, Senior Fellow, The Salk Institute for Biological Studies: "Science in the New Humanism."
>
> Phillip Morrison, Professor of Physics, M.I.T., "Human Values Under the Impact of Science."
>
> George Wald, Professor of Biology, Harvard University: "Science and the Human Endeavor."
>
> Arnold Arons, Professor of Physics, Amherst College: "Cultivating Humanistic Perspectives Toward Science in Our Future Teachers."
>
> Raymond J. Seeger, Senior Staff Associate for Research, National Science Foundation: "The Role of the History of Science in Teaching the New Humanism."[25]

---

[23] "Science Education in American Schools," Forty-sixth Yearbook, Part I. National Society for the Study of Education, Chicago: University of Chicago Press, 1947, p. 306.

[24] "Rethinking Science Education," Fifty-ninth Yearbook, Part I. National Society for the Study of Education, Bloomington, Ill.: Public School Publishing Co., 1960, p. 1.

[25] Programs for the National Science Teachers Convention, Washington, D.C., March 29 to April 2, 1968.

In October of 1968, the editors of The Science Teacher selected Vincent N. Lunetta as recipient of their annual Science Teacher Achievement Recognition Award. In connection with his award-winning entry, Lunetta had written:

> If the educational process is to be effective in a technological culture, the layman must understand in some depth the relationships existing among the social sciences, the humanities and the natural sciences.[26]

Lunetta also claimed that while secondary schools are moderately successful in providing the background needed by the future scientist, little was being done to demonstrate the relationships previously mentioned, and as a result, present courses lacked relevance for most secondary students.[27] Others added their voices to the same point. Former ambassador to Russia Foy Kohler suggested similar modification of current science courses. Said Kohler:

> The introductory courses in the natural sciences continue to be subject-matter oriented; they tend to be encylopedic in nature. I do not believe that such courses are of great value to the majority of students who do not follow scientific or science-related careers. Students preparing for careers in foreign affairs, for example, do not need to know how to dissect a specimen, the differences in the molecular structure of substances nor the details of atomic structure. . . . I would far rather see young people preparing for careers in foreign affairs provided with an appreciation of the principles and

---

[26]Vincent N. Lunetta, "Science and Man," The Science Teacher, Vol. 35, No. 7, Oct., 1968, pp. 33.

[27]Ibid., p. 33.

> achievements of science and technology as they relate to the American civilization and international affairs. They should gain an understanding of the ways in which science and technology operate to alter our lives and how these forces of our time can affect the tenor and character of our world.[28]

Two other educators pursued the possibility that courses in the history of science might illustrate the interrelationships of science and society. Willard William Korth developed a test for determining the student's concept of the social aspects of science, then used this instrument to determine if a science unit dealing with the history of science could favorably affect this concept. Korth found that the experimental treatment did have an effect in promoting an understanding of the social aspects of science, but he also found that certain student misconceptions were resistant to change.[29]

Another researcher, Kendall Wight Baxter, studied the relative effectiveness of three methods of teaching physical science. Baxter compared a subject matter centered approach, a historical approach which emphasized social and cultural interrelationships, and a historical

---

[28]Foy D. Kohler, "The Non-Scientist Speaks on Science for a Liberal Education," The Science Teacher, Vol. 35, No. 4, April, 1968, p. 13.

[29]Willard William Korth, "The Use of the History of Science to Promote Student Understanding of the Social Aspects of Science," (unpublished Doctoral Thesis, Stanford University, Palo Alto, California, 1968) 65 pages.

approach with laboratory experiments.[30] All three approaches were taught by the same person. Baxter used the Test on Understanding Science, Form W, and his own subject matter tests to measure the relative effectiveness of each approach. Baxter's conclusions: No approach was significantly better in imparting subject matter. The historical approach which emphasized social and cultural interrelationships was the most effective in developing an understanding of scientific endeavors.

Matthew J. Brennan, Director of the Pinchot Institute for Conservation Studies, suggested that science teachers might include conservation as a worthy topic. Brennan wrote:

> We have reached the point in science education where fourth graders are talking about DNA molecules, but their own environment is still unknown to them. A change is due. . . . Population is the greatest problem facing man. All other resource problems can be traced to man's increased needs for food, fiber and living space. An understanding of population should be the greatest problem facing science education. It is the greatest problem facing conservation.[31]

Certain sections of the Wong-Dolmatz Ideas and Investigations in Science text which was published in 1971 dealt

---

[30]Kendall Wight Baxter, "A Comparative Study of the Effectiveness of Three Methods of Teaching a General Education Physical Science Course," (unpublished Doctoral Thesis, Colorado State College, Greeley, Colorado, 1968) 142 pages.

[31]Matthew J. Brennan, "Conservation As An Area of Study Appropriate to Science," The Science Teacher, Vol. 34, No. 4, April, 1967, p. 17.

with the problems Brennan described.[32] However, what was really noteworthy about the Wong-Dolmatz text was the extensive effort to make science seem more relevant by dealing with the scientific aspects of familiar things in a very pictorial manner. Aimed at the high school student who is a poor reader, the Wong-Dolmatz text has found acceptance in many inner-city schools.

Later, other texts followed this same pattern. In Life Science Investigations: Man and the Environment, Holobinko, Showalter and Rassmussen dealt with such ecological problems as the death of Lake Erie.[33]

Thus far a survey of the literature has identified some of the shortcomings of the process-oriented courses and has described the move toward science courses having closer ties with the humanities. It is now appropriate to examine the philosophical foundation of such courses.

The Rationale for Science Courses Which Emphasize the Humanistic Aspect of Science

As Milton O. Pella[34] and the late Harold E. Wise[35] have pointed out, in a democracy it is especially important

---

[32]Malvin S. Dolmatz and Harry K. Wong, Ideas and Investigations in Science, (Englewood Cliffs: Prentice-Hall, Inc., 1971).

[33]Paul Holobinko, Fredrick A. Rassmussen and Victor M. Showalter, Life Science Investigations: Man and the Environment, (Boston: Houghton Mifflin Co., 1971).

[34]Pella, Op. Cit.

[35]Harold E. Wise, "Science and Civic Responsibility," Science Education, Vol. 49, No. 3, April, 1965, p. 196.

that all citizens as well as civic leaders understand the effect of scientific developments. Without this understanding, it is extremely difficult to make intelligent decisions regarding complex problems. A chilling example of this is provided by Ritchie Calder, who describes Clement Attlee's comment on his part in the 1945 decision to drop the atomic bomb on Hiroshima:

> All I knew was that it was a bigger bomb. I knew nothing at all about fall-out, nor the genetic effects. And as far as I know President Truman and Winston Churchill knew nothing of those things either. Whether the scientists directly concerned knew, or guessed, I do not know. But, as far as I am aware, they said nothing of it to those who had to make the decision.[36]

It is worth noting that scientists had known about radiation-produced mutations since 1927.

Paradoxically, despite the fact that the average layman cannot claim to be knowledgeable about scientific affairs, the public is now clamoring for a greater voice in decisions involving science. In "Science in Human Affairs," Rene' J. Dubos describes this thrust:

> After World War II, and especially after Sputnik I, scientists were given almost carte blanche with regard to the utilization of funds appropriated by Congress for scientific research. It was then taken for granted that only scientists were competent to determine how the scientific enterprise should be managed. A striking contrast to this laissez-faire attitude has come to light during recent public debates on scientific policy. Numerous members of the

---

[36]Ritchie Calder, "Common Understanding of Science," Impact of Science on Society, XIV, 1964, p. 187.

> executive branch of Congress have emphatically stated that public bodies must have a dominant voice in deciding which scientific problems are of greatest social importance, and, therefore, which ones deserve priority and greatest public support. In fact, several congressional committees are attempting to formulate an overall strategy for the scientific effort--leaving to scientists, of course, the task of developing the tactics best suited to this strategy.[37]

The public's thrust for a greater role in decision-making in scientific matters makes it even more imperative that science education concern itself with developing an understanding of the interrelationships of science and society.

How can educators best go about developing this understanding? Originally it was thought that if the student simply took several courses in the "basic sciences," i.e., chemistry, biology and physics, that he would gain an understanding of the place of science in civilization. Unfortunately, even though this belief is still held by many people, an increasing number of educators now agree that simply taking these courses does not help one to develop such an understanding. Speaking to this point, Eric Hutchinson says:

> That chemistry or physics is a necessary component of a liberal education is a proposition that needs no lengthy justification in American society in the middle of the twentieth century. I shall argue in this paper, however, that the presence of chemistry and physics in a college curriculum

---

[37]Rene' J. Dubos, "Science in Human Affairs," The Science Teacher, Vol. 34, No. 5, May, 1967, p. 11-12.

> is not a sufficient condition for a liberal education unless the subjects are carefully taught.[38]

Later, Hutchinson suggests what he means by the phrase "carefully taught."

> I should like to propose an enlargement of educational goals. We can agree on the necessity of providing a liberal education in the sciences, emphasizing the human activity of science even if we are obliged to dip selectively, and perhaps shallowly, into the body of knowledge. The common good and democratic evaluation of science as a component of the common good demand this.[39]

Addressing much the same problem, J. A. Battle says:

> Today the American child is being drowned in knowledge, new and old. When he most needs a lifeline to keep from sinking in this "raw" knowledge, he is given still more "raw" knowledge. Instead of only handing out more knowledge it is our task as teachers to help the young to integrate knowledge with values, thought, and behavior. Only when there is such an integration will education be made relevant to life. To offer educational programs that are irrelevant to life is to reduce education to an absurdity.[40]

Battle's point concerning the integration of knowledge with values is an important one. Although Morris Kline makes use of different terms, what he says conveys essentially the same meaning. Kline says that what counts

---

[38]Eric Hutchinson, "Science: A Component of Liberal Education," <u>Journal of Chemical Education</u>, Vol. 44, No. 5, May, 1967, p. 261.

[39]<u>Ibid</u>., p. 265.

[40]J. A. Battle and Robert L. Shannon, <u>The New Idea in Education</u> (N.Y.: Harper and Row Publishers, 1968), p. 90-91.

is an awareness of the significance of knowledge, or wisdom.[41]

A Summary: The Philosophical Foundations of Courses Which Emphasize the Humanistic Aspect of Science

One can conclude that there is a basic foundation upon which the humanistically-oriented science courses stand: That is, in a democracy, all citizens must be aware of the significance of scientific knowledge if they are to intelligently participate in the decision-making process.

However, both the traditional science courses, which tend to be collections of scientific facts and concepts, and the current process-oriented science courses, which emphasize laboratory problem solving, seemingly fail to develop this awareness because they present science as a subject having little connection with human affairs.

When science is presented in this manner, students fail to see how science is related to human affairs and hence are unable to place it in their own particular hierarchy of values. When this happens, students say that the subject "lacks relevance" for them, and enroll in other courses. The humanistically-oriented science courses represent an attempt to solve this problem.

---

[41]Morris Kline, "The Liberal Education Values of Science," The Science Teacher, Vol. 32, No. 8, Nov., 1965, p. 22.

Developing Some Guidelines for Humanistically-Oriented Science Courses

Having observed the trends in science education and having examined the rationale for these trends, it is now appropriate to consider the development of guidelines for the curriculum materials to be created.

It is increasingly evident that modern curriculum materials in science cannot be an encyclopedic compilation of scientific facts and concepts which are basic to further study in the field. Such curricula really contribute more to "technical training" than they do to the objectives of a liberal education.

Likewise, modern curriculum materials in science cannot be so oriented to laboratory experimentation and activities involving problem solving that they neglect other educational objectives. In order to gain wider acceptance, modern curriculum materials must meet a wide range of objectives. Most important of all, these curriculum materials must bring about an awareness of the significance of science to civilization.

In order to develop an understanding of the value of science to civilization, science must be presented as an integral part of civilization. This means that modern science courses will be more ecologically and humanistically oriented. Most of the topics covered should be developed in terms of how they affect the human sphere of interest.

The review of the literature reveals several types of science courses that are capable of presenting science as a part of civilization. The first of these courses places heavy emphasis on the history of science. It is likely that the science materials utilizing this approach will cut across several boundary lines, dipping selectively into history, economics and sociology. This suggests that such courses will contain materials and concepts formerly considered to be the exclusive property of the field of social studies. Such action is of necessity, because in order to illustrate the effect of science on society, it is necessary to describe the lives of people, the conditions of the time, and the changes brought about by advances in scientific knowledge.

A second type of course which may help educators to present science as a part of civilization emphasizes the scientific aspect of present problems. For example, with approximately one-half of the people of the world hungry or malnourished, the contributions of the science of genetics to the problems of crop improvement assume greater proportions.[42]

Lastly, as mentioned previously, modern science curriculum materials should be aimed at teaching students something about the role of science in civilization rather than presenting a more limited technical type of course. Implementing this philosophy, modern science curriculum

---

[42] George Borgstrom, The Hungry Planet, (New York: Collier Books, 1967) p. xi.

materials need not be as technical; i.e., they need not emphasize mathematics and nomenclature as they have in the past; instead modern science materials need take pains to relate science to the activities and problems of past and present times. Science should be presented in its proper setting if the student is to see it in the proper perspective.

As a result of experiencing curriculum materials developed along these guidelines, it is possible that students may command less scientific knowledge, but, as adults, will hopefully show greater wisdom in their reactions to scientific matters.

In the final analysis, what this philosophy advocates is giving students a new viewpoint of the goals of science teaching. Originally, science courses led students to see science as a body of information to be learned. Later, with the rise of the process-oriented courses, students saw science as a method of solving laboratory problems. Hopefully, the humanistically-oriented science courses will be successful in presenting science as one of the more important ways in which man can improve his life on earth.

The Humanistically-Oriented Science Curriculum Materials

For teachers interested in preparing and utilizing humanistically-oriented curriculum materials, the units appearing in Appendix C may be of significant value. Although these materials were specifically designed and developed for this research effort, the physical bulk of the materials necessitate their separation from the more succinct sections of this study.

Organization of the Thesis

The first section of this chapter was concerned with the suggestions of educators regarding curriculum materials in science. The second section attempted to draw some guidelines for the materials to be created as part of this study. These guidelines took into consideration the suggestions described in the first section.

Chapter three will be devoted to a discussion of the design of the study. In chapter four the results of the evaluation and an analysis of the data collected will be presented. In chapter five a summary, conclusions and recommendations for further study will be discussed.

CHAPTER III

DESIGN OF THE STUDY

An Overview of Chapter III

As discussed in the review of the literature, it seems obvious that both traditional and process-oriented science courses have deficiencies that make them less than completely acceptable to all educators. Apparently, many critics seem to feel that neither type of science course does an adequate job of illustrating the value of science. Agreement with this criticism led to the construction of the humanistically-oriented science curriculum materials which are presented in the appendix of this thesis. These materials make a strong effort to increase the value which students attach to scientific endeavors by dealing with some scientific activities in terms of their contribution to civilization. Many of the scientific activities described in these materials are also common to both process-oriented and traditional science courses.

During the 1972-1973 school year, these humanistically-oriented science curriculum materials were used to instruct several groups of high school students in science. To access the relative effectiveness of these materials, a research instrument was designed to determine the relative value which this group of students attached to certain scientific activities as compared to the value placed on the same activities by groups of students having taken traditional and process-oriented courses. In this chapter, the details of the study will be described.

Development of an Instrument

The humanistically-oriented science curriculum materials presented in the appendix were designed so that they dealt with six scientific activities that were also covered by both the Introductory Physical Science course and the Chemical Education Materials Study Program. These six activities were:

(1) The determination of the melting point of solids.

(2) The use of fractional distillation to separate one or more liquids from a mixture.

(3) The use of fractional crystallization as a means of separating dissolved solids.

(4) The separation of a mixture of solids through the use of a variety of solvents.

(5) The use of spectral analysis as a means to the identification of substances.

(6) The determination of the density of substances.

As expected, no existing research instruments were available which dealt with student value formation with regard to these specific six activities. To fill this void, an instrument was developed. Lists of several hundred scientific, technological and historical events were drawn up. Examples of such events follow:

(1) Engineers complete construction of the Golden Gate Bridge.

(2) The planet Pluto is discovered by astronomers.

(3) Gold is discovered at Sutter's Mill in California.

The six activities dealt with by the humanistically-oriented science curriculum materials, The Chemical Education Materials Study, and the Introductory Physical Science course were also put in the form of a series of events. By rephrasing the form of these six statements, a list of thirty of these events was developed.

Next, a series of twenty-five items was constructed. Each item consisted of four events chosen from the lists previously described. Of the four events making up an item, one event was always selected from the list which was drawn from the scientific activities which the Introductory Physical Science course, the Chemical Education Materials Study and the humanistically-oriented science curriculum materials had in common. The remaining three events needed to complete the item were drawn from the lists of scientific, technological and historic events. Later students would be asked to arrange the four events making up each item in order of greatest to least valuable contribution to civilization.

Careful selection of events was employed so that in some items most of the events were historical, while in other items, most of the events were scientific or technological. The four events making up the various items were also selected so that in some items a well-informed person might select the historical event as being the most valuable, while in other items, a better selection would be a scientific event, technological event, or one of the events taken from the Introductory Physical Science-Chemical Education Materials Study-humanistically-oriented science curriculum materials list.

The list of twenty-five items was analyzed by a panel of seven experienced science teachers. On the basis of this panel's analysis, the list was revised and a pilot instrument was constructed. This instrument and the overall design of the study were then submitted to the Office of Research Consultation at Michigan State University. After suggestions from this office, a pilot instrument was developed. The pilot instrument was then administered to thirty-one students selected at random from a ninth grade class grouping. Data obtained from the pilot instrument was tabulated, and each of the thirty-one ninth grade students involved in the testing of the pilot instrument was interviewed regarding his or her responses. On the basis of these student interviews, the instrument was further refined, and twelve items were selected on the basis of greatest validity. The final polished instrument appears in Appendix A; hereafter, this instrument is referred to by the abbreviation VOS.

Responses were to be scored in the following manner: In each of the twelve items the event drawn from the Introductory Physical Science-Chemical Education Materials Study-humanistically-oriented science curriculum materials list was identified. If a student selected this event as being of "greatest value," four points were scored; a rating of this event as being of "second greatest value" received three points. Ratings of "third greatest value," and of "least value" received two points and one point respectively. Thus, if the student rated all twelve of the events drawn from the Introductory Physical Science-Chemical Education Materials Study-humanistically-oriented science curriculum materials list as being of greatest value, the result would be a score of twelve times four, or forty-eight. A score of thirty would result from random selection, and the lowest score possible, resulting from twelve responses of "least value," would be a score of twelve. In all, a student would make forty-eight value judgments regarding the events listed.

The Sample

Samples were drawn from the freshman, junior and senior classes of a large high school located in the suburban area west of Chicago. This suburb contains a mixture of blue and white collar workers, but the per capita income is somewhat above the average for the United States. However, the level of educational aspiration is below the national average, with only about thirty percent of the 1972 graduating class enrolling in a four year college.

In the high school in question, one year of science is required for graduation. As a result of this requirement, almost all freshmen take a science course. Virtually the only freshmen not enrolled in science are those in special programs for the educable mentally handicapped. On the basis of past achievement, I.Q. scores, and tests taken during the eighth grade, freshmen students enrolling in science are placed in either Introductory Physical Science or Science 9. Roughly the top two-thirds of the freshman class are placed in the Introductory Physical Science course, while the academically less talented lower one-third of the freshman class take Science 9. Scores on the Scholastic Testing Services I.Q. Test show that the students taking the Introductory Physical Science course have an average I.Q. of 115, while those taking Science 9 have an average I.Q. of 90. On this particular test, the I.Q. of the average high school student is 108.

The sample also included all the juniors and seniors who were enrolled in chemistry during the 1972-1973 school year. The average I.Q. of these students, as measured by the Henmon-Nelson I.Q. Test was approximately 120. There were slightly more boys than girls in these classes and about four times as many juniors as seniors. Some of the most academic students in the school were in these classes.

The treatment group, who received instruction using the humanistically-oriented science curriculum materials which appear in the appendix, consisted of two Science 9 classes and three chemistry classes. There were a total of 38 students in the Science 9 classes and 61 students in the chemistry classes. The non-treatment group received instruction in science using the Introductory Physical Science materials, or the Chemical Education Materials Study program. This group consisted of two chemistry classes and seventeen Introductory Physical Science classes. Thirty-one students were enrolled in these chemistry classes and 421 students were enrolled in the Introductory Physical Science classes. Thus, the treatment group consisted of five classes and 99 students, while the non-treatment group consisted of nineteen classes and 452 students.

Treatment

The different classes making up the non-treatment group were taught Introductory Physical Science or chemistry by seven different teachers. Some of these teachers felt that student realization of the value of science was an important objective, while others were barely aware of this objective. As a group, these teachers were very well prepared. Four of the seven teachers possessed masters degrees, and the other three were nearing completion of their masters degrees. The average number of years of teaching experience for this group approximately was five years, ranging from three years to ten years. All of the teachers teaching the Introductory Physical Science course had taken special training for the teaching of this course and with the exception of one teacher, had previously taught the Introductory Physical Science course at least twice. The chemistry classes in the non-treatment group were taught by a teacher having an undergraduate major in chemistry and a masters degree in physics teaching. The treatment group was also taught by one teacher. This teacher had a masters degree, nearly twenty years of teaching experience, and felt strongly that student realization of the importance of science was an important objective.

The different classes making up the treatment group were instructed in science using the humanistically-oriented science curriculum materials which appear in Appendix C of this thesis. For the two classes of Science 9 students, approximately ten weeks were required to cover these materials. It was necessary to give superficial coverage to many of the more mathematical sections of these materials with these classes. For example, section 2.5 of the humanistically-oriented materials discusses molecular weight determinations. While average or above average students could be expected to master the mathematics involved in this section, it was considered sufficient if the low level Science 9 students were able to see that molecular weights may be determined by studying the freezing point of solutions.

The three chemistry classes involved in the treatment group contained students of much higher ability than the Science 9 classes and, for this reason, were able to cover the same material in somewhat less time. All classes met for a forty-eight minute period five times a week.

Throughout the unit, short quizzes were given. Approximately one-half of the quiz items were of a general, factual nature; the remainder dealt with the value of the activity. For example, in a quiz dealing with section 2.2, the questions used were:

(1) What is the density of a solid which has a mass of 18 grams and a volume of 2 cubic centimeters?

(2) Why is it important that mankind have knowledge of the densities and melting points of the known substances?

The approximate time schedule and the activities which were utilized with the Science 9 classes appear in Appendix C.

Evaluation Procedures

Prior to treatment, all groups involved in the study were given the VOS Opinion Poll as a pre-test. The mean score of each class on the VOS Opinion Poll was computed and recorded for future reference. Following the pre-test, treatment was administered as previously outlined. At the conclusion of the treatment period, the VOS Opinion Poll was again administered to all of the groups involved in the study.

Analysis of the Data

The hypotheses to be tested follow:

(1) Prior to treatment, the mean score of the VOS Opinion Poll made by classes in both treatment and non-treatment groups will be the same.

(2) Following treatment, the mean score on the VOS Opinion Poll made by classes in both treatment and non-treatment groups will be the same.

Should the test of the latter hypothesis fail, the following alternate hypothesis will be examined:

> Following treatment, the mean score on the VOS Opinion Poll made by classes which are part of the treatment group will exceed that of the classes which are part of the non-treatment group.

These hypotheses will be tested by computing *t* scores to determine whether differences exist between the treatment and non-treatment groups at the .95 level of significance.

The decision to analyze the data using classrooms as a unit was based on the fact that students received instruction as a class and that interaction between students occurred within the classroom. Under these conditions, it was deemed inappropriate to use the mean scores of students in the treatment and non-treatment groups as the unit of analysis.

Summary

In Chapters I and II of this thesis, the need for more humanistically-oriented science curriculum materials was discussed. Subsequently, such materials were developed; they appear in Appendix C of this thesis. These materials were designed so that they covered six activities that were also covered by the Chemical Education Materials Study, and by the Introductory Physical Science course. These humanistically-oriented science curriculum materials were later used to instruct five classes of students in science for a ten week period of time.

To assess the effectiveness of these materials as compared with the Introductory Physical Science course or the Chemical Education Materials Study program, an instrument was developed. Lists of scientific, technological, and historical events were drawn up. The six activities which were common to the Introductory Physical Science course, the Chemical Education Materials Study program and the humanistically-oriented science curriculum materials were also put in the form of a list of events. From these lists, a series of twenty-five items, each of which contained four events, was constructed. Each item consisted of one event drawn from the list of activities shared by the three science courses and of three events drawn from the lists of historic, scientific and technological events. This list of items was analyzed by a panel of seven experienced science teachers. On the basis of suggestions by these teachers, the list of items was revised and organized into the form of a pilot instrument. The pilot instrument was administered to thirty-one ninth grade students.

Data obtained from the pilot instrument was analyzed, and each of the thirty-one students was interviewed regarding his responses. On the basis of these interviews, the instrument was further revised and twelve items were selected on the basis of greatest validity. This revision was named the "VOS Opinion Poll." The final, polished instrument was administered as a pre-test to both treatment and non-treatment groups.

Treatment consisted of ten weeks of instruction using the humanistically-oriented science curriculum materials previously developed. During this same period of time, the non-treatment group continued to receive instruction in science using either the Introductory Physical Science materials or the Chemical Education Materials Study program. Following treatment, the VOS Opinion Poll was again administered to both treatment and non-treatment groups.

In planning the analysis of data, it was decided to test the hypothesis that:

> Following treatment, the mean score on the VOS Opinion Poll made by classes in both treatment and non-treatment groups will be the same.

This hypothesis, and possibly the alternate hypothesis, were to be tested by computing *t* scores to determine whether or not differences existed in the means of the two groups at the .95 level of significance.

CHAPTER IV

ANALYSIS OF DATA

Data Collected - Pre-Test

The following data were collected prior to treatment.

Table 1. Mean scores made by treatment and non-treatment groups on the VOS Opinion Poll prior to treatment.

Part I. Mean scores made by classes making up the treatment group.

Science 9 Classes	Chemistry Classes
28.43	30.21
29.17	31.17
	32.04

Part II. Mean scores made by classes making up the non-treatment group.

Introductory Physical Science Classes				Chemistry Classes Using the Chemical Education Materials Study Program
26.21	28.06	28.94	29.65	30.85
27.38	28.68	29.20	29.67	31.57
27.80	28.73	29.35	30.01	
27.97	28.86	29.43	30.23	
			30.71	

The grand mean for the classes making up the treatment and non-treatment groups is shown in Table 2.

Table 2. The grand mean of classes making up the treatment and non-treatment groups.

Pre-Test VOS Opinion Poll	Grand Mean for Classes in the Treatment Group	Grand Mean for Classes in the Non-Treatment Group
	30.20	29.12

<u>Analysis of Pre-Test Data</u>

The hypothesis to be tested follows:

(1) Prior to treatment, the mean score on the VOS Opinion Poll made by classes in both treatment and non-treatment groups will be the same.

Computation of the difference between these means indicates that the grand mean of the treatment group exceeds that of the non-treatment group by 1.08. When a <u>t</u> score is computed using this data, the difference cited is found to be insignificant at the .95 confidence level; thus the hypothesis stated must be accepted. However, the difference is significant at the .90 confidence level. While this indicates that the treatment group places slightly greater value on the scientific activities involved in the study even before treatment, this difference was anticipated. The treatment group consisted of three chemistry classes and two Science 9 classes and seventeen Introductory Physical Science classes. Since chemistry is a subject ordinarily selected only by those students who see a need for additional science courses beyond the required one year of science, students taking chemistry may place a greater value on scientific activity than do other students. Since three out of the five classes within the treatment group were chemistry classes, compared to only two classes out of the nineteen classes composing the non-treatment group, it was assumed that the grand mean of the treatment group might be higher.

When the grand mean of the Introductory Physical Science classes in the non-treatment group is compared to the grand mean of the Science 9 classes, little difference exists.

Table 3. A comparison of the grand mean made on the VOS Opinion Poll by Science 9 classes and Introductory Physical Science classes prior to treatment.

Pre-Test, VOS Opinion Poll	Grand Mean, Science 9 Classes in Treatment Group	Grand Mean, Introductory Physical Science Classes in Non-Treatment Group
	28.80	28.87

These data may be used to test the following hypothesis:

(2) Prior to treatment, the grand mean on the VOS Opinion Poll made by Introductory Physical Science classes which are part of the non-treatment group, and Science 9 classes which are part of the treatment group, will be the same.

A difference of only .07 exists between these two grand means. Computation of a t score for this data reveals that this difference is not significant, even at the .55 level of confidence. Thus, the hypothesis stated may be accepted.

Similarly, when the grand mean of the chemistry classes in the non-treatment group is compared to the grand mean of the chemistry classes in the treatment group, little difference is found to exist between these groups.

Table 4. A comparison of the grand mean of chemistry classes in both treatment and non-treatment groups.

Pre-Test, VOS Opinion Poll	Grand Mean, Chemistry Classes in Treatment Group	Grand Mean, Chemistry Classes in Non-Treatment Group
	31.14	31.21

This difference, .07, is not significant, even at the .55 confidence level. Thus, the following hypothesis may be accepted:

> (3) Prior to treatment, the grand mean on the VOS Opinion Poll made by chemistry classes which are part of the non-treatment group, and that of chemistry classes which are part of the treatment group, will be the same.

Data Collected - Post-Test

Following treatment, the VOS Opinion Poll was again administered to both treatment and non-treatment groups and the following data was collected.

Table 5. Mean scores made by treatment and non-treatment groups on the VOS Opinion Poll following treatment.

Part I. Mean scores made by classes making up the treatment group.

Science 9 Classes	Chemistry Classes
37.75	40.23
38.37	41.35
	42.43

Part II. Mean scores made by classes making up the non-treatment group.

Introductory Physical Science Classes				Chemistry Classes Using the Chemical Education Materials Study Program
25.83	28.42	28.96	29.87	30.26
26.80	28.47	29.23	30.53	32.08
27.50	28.57	29.51	30.53	
28.26	28.91	29.53	31.23	
			31.30	

The grand mean for the classes making up the treatment and non-treatment groups is shown in Table 6.

Table 6. The grand mean of classes making up the treatment and non-treatment groups.

Post-Test, VOS Opinion Poll	Grand Mean for Classes in the Treatment Group	Grand Mean for Classes in the Non-Treatment Group
	40.02	29.25

Analysis of Post-Test Data

The hypothesis to be tested follows:

> (4) Following treatment, the grand mean on the VOS Opinion Poll made by classes in both treatment and non-treatment groups will be the same.

Should a test of this hypothesis fail, the following alternate hypothesis will be examined:

> (4a) Following treatment, the grand mean on the VOS Opinion Poll made by the treatment group will exceed that of the non-treatment group.

To test the null hypothesis, a $\underline{t}$ score was computed using the grand means of the treatment and non-treatment groups. This computation shows $\underline{t} = 13.72$; since $\underline{t} = 2.82$ at the .995 level of confidence, the null hypothesis must be rejected. The alternative hypothesis, that the grand mean of the treatment group exceeds that of the non-treatment group must be accepted.

Further Considerations and Analyses

As was pointed out earlier, on the VOS Opinion Poll pre-test, the grand mean of the treatment group exceeded the grand mean of the non-treatment group by 1.08, a figure which was significant at the .90 confidence level. Although the difference in the grand means of these two groups on the post-test, 10.77, far exceeds the original difference, it is worthwhile to examine the post-treatment data from a slightly different viewpoint. The fact that the treatment group had a higher mean score on the pre-test was attributed to the fact that this group contained a higher percentage of students who may have placed a greater value on scientific activity than did the treatment group. Accordingly, the pre-test data for both the treatment and non-treatment groups were broken down into groups consisting of chemistry students, Introductory Physical Science students, and Science 9 students. When this was done, no significant differences in the pre-test scores made by Introductory Physical Science students in the non-treatment group and Science 9 students in the treatment group were present. Similarly, no significant differences in the pre-test scores made by chemistry students in the treatment group and chemistry students in the non-treatment group were detected.

If the post-treatment data is broken down in the same manner, these figures emerge:

Table 7. A comparison of the grand mean of various classes in the treatment and non-treatment groups.

Post-Test, VOS Opinion Poll	Grand Mean, Science 9 Classes in Treatment Group	Grand Mean, Introductory Physical Science Classes in Non-Treatment Group
	38.06	29.02
Post-Test, VOS Opinion Poll	**Grand Mean, Chemistry Classes in Treatment Group**	**Grand Mean, Chemistry Classes in Non-Treatment Group**
	41.33	31.17

The hypothesis to be tested is:

> (5) Following treatment, the grand mean on the VOS Opinion Poll made by Introductory Physical Science classes which are part of the non-treatment group, and that of Science 9 classes which are part of the treatment group, will be the same.

The difference between the grand mean of the Introductory Physical Science classes in the non-treatment group and Science 9 classes in the treatment group is 9.04. When a *t* score for this data is computed, *t* is found to equal 9.55, a figure which far exceeds the value required for significance at the .995 level of confidence. The hypothesis previously stated must be rejected, and the following alternative hypothesis must be accepted:

> (5a) Following treatment, the grand mean on the VOS Opinion Poll made by Science 9 classes which are part of the treatment group will exceed that of the Introductory Physical Science classes which are part of the non-treatment group.

Similarly, a second hypothesis may be tested:

> (6) Following treatment, the grand mean on the VOS Opinion Poll made by chemistry classes which are part of the non-treatment group and that of chemistry classes which are part of the treatment group will be the same.

The difference between the grand mean of the chemistry classes in the non-treatment group and chemistry classes in the treatment group is 10.16. For these data, *t* is found to be 17.5, a figure which far exceeds the value required for significance at the .995 level of confidence. Thus, the hypothesis previously stated must be rejected, and the following alternate hypothesis accepted:

> (6a) Following treatment, the grand mean on the VOS Opinion Poll made by chemistry classes which are part of the treatment group will exceed that of chemistry classes which are part of the non-treatment group.

Lastly, it may be noted that the grand mean of the Introductory Physical Science classes in the non-treatment group increased from 28.87 on the pre-test to 29.02 on the post-test. Similarly, the grand mean for the chemistry classes in the non-treatment group decreased from 31.21 on the pre-test to 31.17 on the post-test. These data may be used to examine the following hypotheses:

> (7) The grand mean on the VOS Opinion Poll made by Introductory Physical Science students who were part of the non-treatment group will be the same on both pre- and post-tests.

> (8) The grand mean on the VOS Opinion Poll made by chemistry students who were part of the non-treatment group will be the same on both pre- and post-tests.

When *t* scores are computed, it is apparent that the first hypothesis may be rejected, but rejection can occur only at the .55 level of confidence. The second hypothesis must be accepted, even at the .55 level of confidence. Plainly, only minimal or insignificant changes have occurred in the values of these groups as measured by the VOS Opinion Poll. This is not the case for classes in the treatment group, however. The increase shown between pre- and post-treatment grand means for Science 9 classes was 9.26. Chemistry classes, which were also part of the treatment group, showed an increase in pre- and post-treatment grand means of 10.19. These data may be used to examine the following hypotheses:

> (9) The grand mean on the VOS Opinion Poll made by Science 9 classes who were part of the treatment group will be the same on both pre- and post-tests.

> (10) The grand mean on the VOS Opinion Poll made by chemistry students who were part of the treatment group will be the same on both pre- and post-tests.

When *t* scores are computed using these data, the values computed far exceed those required for significance at the .995 level of confidence. Accordingly, both hypotheses must be rejected, and the following alternate hypotheses accepted:

> (9a) The mean score on the VOS Opinion Poll made by Science 9 classes who were part of the treatment group will be higher on the post-test than on the pre-test.

> (10a) The mean score on the VOS Opinion Poll made by chemistry classes who were part of the treatment group will be higher on the post-test than on the pre-test.

Clearly, a significant change has occurred in the values of these groups as measured by the VOS Opinion Poll.

Summary

Prior to treatment, the VOS Opinion Poll was administered to both treatment and non-treatment groups. Because of the probability of interaction between students within each classroom, it was decided to use the classroom as the unit of analysis. Mean scores were computed for each classroom in both treatment and non-treatment groups. Using these data, the grand means for both treatment and non-treatment groups were computed. The grand mean of the non-treatment group, 30.20, exceeded the grand mean of the treatment group, which was 29.12, by 1.08. This difference was significant at the .90 confidence level, but this difference had been anticipated, because the treatment group consisted of three chemistry classes and two Science 9 classes, while the non-treatment group consisted of two chemistry classes and seventeen Introductory Physical Science classes. It was assumed that chemistry students might place a greater value on scientific activity than do students who do not take chemistry and therefore the higher percentage of chemistry students in the treatment group was possibly responsible for the slightly higher grand mean of the treatment group.

As a research precaution, the treatment and non-treatment groups were broken up into Science 9 classes and chemistry classes in the treatment group, and Introductory Physical Science classes and chemistry classes in the non-treatment group. When the grand mean of Science 9 classes in the treatment group was compared to the grand mean of Introductory Physical Science classes in the non-treatment group, the difference was .07, a value which was not significant, even at the .55 confidence level. Similarly, when the grand mean of chemistry classes in the non-treatment group was compared to the grand mean of chemistry classes in the treatment group, the difference was so slight as to be insignificant, even at the .55 confidence level. Thus, prior to treatment, the treatment and non-treatment groups appeared to be quite comparable in terms of values as measured by the VOS Opinion Poll.

Following treatment, the VOS Opinion Poll was again administered to both treatment and non-treatment groups. The grand mean of the treatment group, 40.02, exceeded that of the non-treatment group, which was 29.25, by 10.77. When a $\underline{t}$ score was computed using these data, this difference was found to be significant at the .995 level of confidence. Thus, the alternate hypothesis, that following treatment, that the grand mean of the treatment group exceeds that of the non-treatment group on the VOS Opinion Poll was accepted.

The data collected following treatment was also examined by comparing Science 9 classes in the treatment group with Introductory Physical Science classes in the non-treatment group. The grand mean on the VOS Opinion Poll made by Science 9 classes following treatment was 38.06, while the grand mean of the Introductory Physical Science classes in the non-treatment group was only 29.02. The difference between these means was 9.04. When a *t* score for these data was computed, the difference was found to be significant at the .995 confidence level.

Similarly, the data collected following treatment was also examined by comparing the grand mean of chemistry classes in the treatment group with that of chemistry classes not in the treatment group. The grand mean of the treatment group was 41.33, while that of the non-treatment group was 31.17. The difference, 10.16, was found to be significant at the .995 level of confidence. This, and the preceeding analysis, led to acceptance of the following hypotheses:

> (1) Following treatment, the mean score on the VOS Opinion Poll of Science 9 classes which are part of the treatment group will exceed that of Introductory Physical Science classes which are part of the non-treatment group.
>
> (2) Following treatment, the mean score on the VOS Opinion Poll of chemistry classes which are part of the treatment group will exceed that of chemistry classes which are part of the non-treatment group.

Lastly, the differences in the pre- and post-treatment grand means of each of the following four groups were examined: Science 9 classes, Introductory Physical Science classes, chemistry classes which were part of the treatment group, and chemistry classes which were part of the non-treatment group. The slight increase and decrease in pre- and post-treatment grand means shown by the Introductory Physical Science classes and the chemistry classes which were part of the non-treatment group were, respectively, insignificant at the .55 confidence level, and barely significant at the same level. By contrast, the large increases in pre- and post-treatment grand means shown by Science 9 and chemistry classes which were part of the treatment group were significant at the .995 level of confidence. These analyses indicate that little or no change occurred in the pre- and post-treatment scores on the VOS Opinion Poll made by the non-treatment group, but that following treatment, significantly higher scores were made on the VOS Opinion Poll by the treatment group.

Table 8. A Summary: Analysis of data collected.

Hypothesis Examined	Difference in Mean Scores	Significance Level	Acceptance or Rejection
(1) Prior to treatment, the grand mean on the VOS Opinion Poll made by classes in both treatment and non-treatment groups will be the same.	1.08	.95	accept

Table 8. Continued

Hypothesis Examined	Difference in Mean Scores	Significance Level	Acceptance or Rejection
(2) Prior to treatment, the grand mean on the VOS Opinion Poll made by Introductory Physical Science classes which were part of the non-treatment group and Science 9 classes which are part of the treatment group, will be the same.	.07	.55	accept
(3) Prior to treatment, the grand mean on the VOS Opinion Poll made by chemistry classes which were part of the non-treatment group, and that of chemistry classes which were part of the treatment group, will be the same.	.07	.55	accept
(4) Following treatment, the grand mean on the VOS Opinion Poll made by classes in both treatment and non-treatment groups will be the same.	10.77	.995	reject

Table 8. Continued

Hypothesis Examined	Difference in Mean Scores	Significance Level	Acceptance or Rejection
(5) Following treatment, the grand mean on the VOS Opinion Poll made by Introductory Physical Science classes which are part of the non-treatment group, and that of Science 9 classes which are part of the treatment group, will be the same.	9.04	.995	reject
(6) Following treatment, the grand mean on the VOS Opinion Poll made by chemistry classes which are part of the treatment group and chemistry classes which are part of the non-treatment group will be the same.	10.16	.995	reject
(7) The grand mean on the VOS Opinion Poll made by Introductory Physical Science students who were part on the non-treatment group will be the same on both pre- and post-tests.	.15	.55	accept
(8) The grand mean on the VOS Opinion Poll made by chemistry students who were part of the non-treatment group will be the same on both pre- and post-tests.	.03	.55	accept

Table 8. Continued

Hypothesis Examined	Difference in Mean Scores	Significance Level	Acceptance or Rejection
(9) The grand mean on the VOS Opinion Poll made by Science 9 classes who were part of the treatment group will be the same on both pre- and post-tests.	9.26	.995	reject
(10) The grand mean on the VOS Opinion Poll made by chemistry students who were part of the treatment group will be the same on both pre- and post-tests.	10.19	.995	reject

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

In order to evaluate and improve existing science courses it is necessary to examine their origins. Originally, most science courses attempted to teach much of what was then known about the various sciences. However, as man's knowledge expanded, this became impossible, and the science courses on the high school level became introductory or preparatory courses for the more advanced science courses which were to follow on the college level. Thus, secondary school science courses originally placed heavy emphasis on mastery of the technical vocabulary and factual content which would be utilized by the student in subsequent, more advanced science courses.

Prior to 1900, the arrangement described was reasonably satisfactory because most of the students then enrolled in secondary schools generally continued their education, taking additional science courses on the college level. However, beginning with the turn of the present century, certain socio-economic changes brought almost all children of school age into the elementary and secondary schools.

Educators soon found that science courses which emphasized mastery of a technical vocabulary and extensive factual content--which could be utilized only in subsequent college-level courses--to be less than completely appropriate for the new, more heterogeneous group of students presently in their classrooms. By 1920 many educators began to insist that science courses be created which were more appropriate for the students then enrolled in U.S. schools. However, as late as 1950, only limited progress in this direction was evident.

In the late 1950s, spurred by the fear that Russia had gained technological superiority over the U.S. massive revisions of U.S. secondary science programs were undertaken. The new science courses, especially those on the upper-middle school level, rejected the traditional emphasis on vocabulary and factual content which had characterized earlier science courses, and moved in a direction which had been previously indicated by psychologist Jerome Bruner. Bruner saw science as a "process of discovery," and urged the development of science courses which utilized this procedure.[1] Many of Bruner's followers saw this procedure as a way to develop students who possessed the mental attributes which were needed to carry on problem solving. As a major figure in the process-oriented Introductory Physical Science Program put it:

> In developing a program on the junior high school level where science is usually

---

[1]Bruner, <u>op. cit.</u>

> mandatory, we wanted to accomplish several things. We wanted the course to help the student to develop his mind as a human being--that is, to learn how to learn, to learn how to be critical, and to learn how to accept or reject the views and data of others . . .[2]

By the mid-1960s, a number of critics began to question the wisdom of the new science courses. The major objections reported centered about the possibility that such educational goals as critical thinking might be very difficult to achieve, and that such courses did little to teach the cultural significance of science. As a result of the latter, claimed the critics, the process-oriented courses failed to provide the student with an enlightened viewpoint regarding the significance of science to civilization. At least one critic suggested that as a result of having taken the process-oriented science courses, students might come to view science as being "devoid of application and relationship to civilization."[3]

The purpose of this study was to develop curriculum materials for use on the high school level which provided a more humanistically-oriented alternative to either traditional or process-oriented science courses and to evaluate the relative success of these materials. The curriculum materials created were designed to illustrate the value of certain specific scientific activities by placing these

---

[2]Uri Haber-Schaim, "IPS Second Edition," Introductory Physical Science Newsletter, Spring, 1972, p. 1.

[3]Tompkins, op. cit., p. 1.

activities in a humanistic setting. These humanistically-oriented curriculum materials were subsequently used in the instruction of ninth, eleventh and twelfth grade students.

To assess the relative effectiveness of these materials, a research instrument, the VOS Opinion Poll, was developed. The VOS Opinion Poll was administered to five classes who subsequently received instruction in science using the humanistically-oriented curriculum materials previously described, and to nineteen classes who were instructed in science using the Introductory Physical Science and Chemical Education Materials Study approaches. Following treatment, the VOS Opinion Poll was again administered to both groups. The mean score made by each of the twenty-four classes was computed, and grand means were computed for both treatment and non-treatment groups.

Although prior to treatment the grand means of the treatment and non-treatment groups had been reasonably comparable, following treatment, the grand mean of the treatment group exceeded that of the non-treatment group by 10.77, a figure which greatly exceeded the value required for significance at the .995 confidence level. The null hypothesis, that the mean score on the VOS Opinion Poll would be the same for classes in both treatment and non-treatment groups, following treatment, was rejected. More detailed analysis indicated that sub-groups of the non-treatment group had made essentially the same scores on both pre- and post-treatment tests, while the mean scores of sub-groups of the treatment group were significantly higher on the post-treatment test.

Conclusions

The data collected and the subsequent statistical analysis carried out allow the following conclusions to be drawn:

1. It is possible to bring about at least a temporary change in the relative value which students attach to specific scientific activities through the use of curriculum materials which have been designed with this objective in mind.
2. It is possible to bring about at least a temporary change in the relative value which both high and low achieving students attach to specific scientific activities.
3. It is unlikely that exposure to scientific information of a technical nature or the performance of laboratory activities will, by themselves, cause most students to attach greater value to science.
4. It may not be as difficult to bring about changes in attitudes and values as is generally thought.

Discussion and Implications

For years, teachers have felt that if students attained factual knowledge that this gain in factual knowledge would automatically be accompanied by the formation of good values and attitudes. Then, in the early 1960s, educators began to support a new approach to the attainment of attitude and value changes:

> More recently a number of workers (e.g., Bruner, 1960) have felt that it is the process of problem solving and discovery in learning that will bring about increased motivation for the subject and all the appropriate interests and attitudes. Their view is that it is not so much what is learned, but how it is learned, which will determine the affective objectives that will be attained at the same time as the cognitive objectives.[4]

The results of this study indicate that courses which emphasize the attainment of factual knowledge and courses which emphasize learning by discovery are both ineffective in bringing about desirable attitude and value changes. Since both of these methods attack the problem of value formation in an indirect manner, expecting value formation to take place automatically, it may be that a more direct approach to this problem is necessary. This suspicion is borne out by the study just described which indicates that value formation will take place if carefully designed curriculum materials, whose major objective is to increase certain values, are employed.

These findings have far reaching implications. Educators have long maintained that the facts are, by themselves,

---

[4]David R. Krathwohl, Benjamin S. Bloom and Bertram S. Masia, Taxonomy of Educational Objectives Handbook II Affective Domain (New York: David McKay Company, Inc.) p. 55.

unimportant. What is important, say educators, is the attitudes and values which possession of the facts brings about. However, if, as the study just concluded indicates, the attainment of factual knowledge is not necessarily accompanied by desirable changes in attitudes and values, then it may be that many of our present secondary science courses should be completely redesigned if educators are really concerned with attitude and value formation, as they claim.

The curriculum materials utilized in this study were unusual in that they placed science in a humanistic setting. Because of this placement, these curriculum materials contain a much greater proportion of material which might ordinarily fall into the realm of the humanities. The success of this approach in changing student values indicates that, for the average student, perhaps a combination of the humanities and the sciences may be better educationally than the present customary combination of mathematics and the sciences. This suggestion has implications for teacher training programs, because, at present, the usual preparation of future science teachers includes few or no courses in the humanities. Perhaps specialized courses dealing with the effect of science on civilization need be developed. In fact, it is quite possible that all introductory science courses on both high school and college levels should follow this theme. Interestingly, a course similar to the one proposed has already been recommended by at least one educator. Tracy M. Sonneborn, Professor of Zoology at Indiana University says:

> My first and major recommendation, the one I have succeeded in activating at Indiana University and believe should be activated in secondary schools, is that biology courses should be designed with a view to the educational needs of the students. Platitudinous and obvious as that may sound, the fact is that biology courses in college have not in general been so designed, and I daresay the same basic criticism is not totally unfounded with regard to secondary school courses.[5]

Later, with regard to the belief that a course which is best for the biology major is also best for the non-major, Sonneborn says:

> I am convinced that this principle is fallacious and that the educational needs of students cannot be satisfactorily met by courses designed primarily to do justice to biology.[6]

Sonneborn's recommendations follow:

> What I recommend, however, for most students is a complete reversal of priorities in the objectives, and a fundamental extension of man-oriented biology to include the social as well as the individual aspects of human biology.[7]

Lastly, regarding the selection of factual material, Sonneborn says:

---

[5]Tracy M. Sonneborn, "Secondary School Preparation for Making Biological Decisions," National Association of Secondary School Principals Bulletin, Vol. 56, No. 360, Jan., 1972, p. 8.

[6]*Ibid.*

[7]*Ibid.*, p. 9.

> . . . the selection of material would be guided by its relevance to the purpose, not by its relevance to doing justice to biology.[8]

Recommendations for Further Study

Scrutiny of this study reveals a number of areas in which further research is needed. First, in the study just concluded, the post-treatment test was administered immediately following treatment. Do the values formed persist, or do they fade with time? How much fading occurs over, say, one year? Studies involving the retention of factual information show that while fading occurs very rapidly, reattainment is quicker than the original acquisition: Is this also true of value formation?

Secondly, is the increased valuation of certain scientific events accompanied by increased valuation of all scientific events? One might expect this transfer to occur, but the extent and distance of carry-over are uncertain.

Lastly, is the increased value which a student places on scientific events accompanied by an increase in the attainment of factual knowledge? For many students, motivation to study science has been lacking. Does placing the sciences in a humanistic setting help supply the missing motivation?

---

[8] Ibid.

A Closing Note

Originally, a major objective of the study just concluded was to develop curriculum materials which would be better able to illustrate the value of science than either process-oriented or traditional science curriculum materials. For a long time, the attainment of factual information has been given the major portion of the teacher's attention. Then, with the rise of the process-oriented courses, the attention shifted to the development of the mental attributes which accompany problem-solving. Neither of these types of courses makes a direct attempt to deal with attitude and value formation. There are probably many reasons for this neglect. As numerous authorities have been quick to point out, so little has been done in the area of attitude and value formation, that even the very statement of objectives dealing with these factors is apt to be meaningless.[9] Procedures for measuring the attainment of values and attitudes are equally poor.[10] In fact, so little has been done in this area, that one can easily become an instant pioneer simply by choosing to work in this area. There is no doubt that the development of attitudes and values is far too important educationally to allow this primitive condition to prevail.

---

[9]Krathwohl, Bloom and Masia, Op. Cit., pp. 21-23.

[10]Richard J. Merrill, "National Assessment of Science Education--A Beginning," National Assessment of Educational Progress Report 1--Science: National Results, (U.S. Government Printing Office, Washington, D.C.) 1970, p. 17.

BIBLIOGRAPHY

BIBLIOGRAPHY

A. BOOKS

Battle, J. A. and Robert L. Shannon. The New Idea in Education. New York: Harper and Row Publishers, 1968.

Bestor, Arthur. The Restoration of Learning. New York: Alfred A. Knopf, 1955.

Borgstrom, George. The Hungry Planet. New York: Collier Books, 1967.

Bruner, Jerome S. The Process of Education. Cambridge: Harvard University Press, 1961.

Dewey, John. Democracy in Education. New York: The Free Press, 1916.

Dewey, John. Lectures in the Philosophy of Education: 1899. New York: Random House, 1966.

Dolmatz, Malvin, and Harry K. Wong. Ideas and Investigations in Science. Englewood Cliffs: Prentice-Hall, Inc., 1971.

Dressel, Paul L. (ed.). Evaluation in the Basic College at Michigan State University. New York: Haper, 1958.

Durant, Will. The Story of Philosophy. New York: Pocket Books, 1953.

General Education in a Free Society. Cambridge: Harvard University Press, 1945.

Holobinko, Paul, Fredrick A. Rassmussen and Victor M. Showalter. Life Science Investigations: Man and the Environment. Boston: Houghton Mifflin Co., 1971.

Hutchins, Robert M. The Conflict in Education in a Democratic Society. New York: Harper Brothers, 1953.

Introductory Physical Science. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1964.

Jacob, Phillip E. Changing Values in College. New York: Harper, 1957.

Krathwohl, David R., Benjamin S. Bloom and Bertram S. Masia. Taxonomy of Educational Objectives Handbook II Affective Domain. New York: David McKay Company, Inc., 1956.

Mayer, Frederich. A History of Educational Thought. Columbus, Ohio: Charles E. Merrill Books, Inc., 1966.

Physics. Boston: D. C. Heath and Co., 1960.

Rickover, Hyman G. Education for Freedom. New York: E. P. Dutton and Co., Inc., 1959.

Wells, H. G. The Outline of History. Garden City, New York: Garden City Books, 1949.

B. PUBLICATIONS OF THE GOVERNMENT, LEARNED SOCIETIES, AND OTHER ORGANIZATIONS

Brown, Kenneth, and Ellsworth Oburn. Offerings and Enrollments in Science and Mathematics. Washington: Government Printing Office, 1957.

Commission on Reorganization of Secondary Education. Reorganization of Science in Secondary Schools, U. S. Bureau of Education Bulletin, No. 26, Washington: Government Printing Office, 1920.

Evins, Joe L. Hearings Before a Subcommittee of the Committee on Appropriations, House of Representatives, 89th Congress. Independent Offices--Appropriations for 1967. Washington: U. S. Government Printing Office, 1966.

Goodlad, John I., Renata von Stoephasius and Francis Klein. The Changing School Curriculum. New York: The Fund for the Advancement of Education, 1966.

Kline, Morris. "The Liberal Educational Values of Mathematics, Science and Technology for Youth," National Education Association, Addresses and Proceedings, pp. 50-67. Washington, D. C.: National Education Association of the United States, 1965.

Merrill, Richard J. "National Assessment of Science Education--A Beginning," National Assessment of Educational Progress Report 1--Science: National Results. Washington: U. S. Government Printing Office, (1970), 15-23.

Program for the National Science Teachers Convention, Washington, D. C., Mar. 29-Apr. 2, 1968.

Rethinking Science Education, pp. 1-17, Fifty-Ninth Yearbook of the National Society for the Study of Education, Part I. Bloomington, Illinois: Public School Publishing Co., 1960.

Rogers, Eric M. "The Research Scientist Looks at the Purposes of Science Teaching," Rethinking Science Education, pp. 19-22. Fifty-ninth Yearbook of the National Society for the Study of Education, Part I. Bloomington, Illinois: Public School Publishing Company, 1960.

"Science Education in the American Schools," Forty-sixth Yearbook, Part I, 306 p., National Society for the Study of Education, Chicago: University of Chicago Press, 1947.

U. S. Office of Education, Education in the U. S. S. R., Bulletin 1957, No. 14. Washington: U. S. Office of Education, 1957.

U. S. Office of Education. Vitalizing Secondary Education. Bulletin 1951, No. 3. Washington: U. S. Office of Education, 1951.

C. PERIODICALS

Anderson, Norman D. "Curriculum in Science," The Science Teacher, Vol. 35, No. 8, (Nov., 1968), 17.

Ausubel, David P. "An Evaluation of the Conceptual Schemes Approach to Science Curriculum Development," Journal of Research in Science Teaching, Vol. III, Issue 4, 255-264.

Brandwein, Paul F. "Observations on Teaching: Overload and Methods of Intelligence," The Science Teacher, Vol. 36, No. 7, (Feb., 1969), 38-40.

Brennan, Matthew J. "Conservation As An Area of Study Appropriate to Science," The Science Teacher, Vol. 34, No. 4, (April, 1967), 16-18.

Calder, Ritchie. "Common Understanding of Science," _Impact of Science on Society_, XIV, (1964), 187-197.

Casteel, Doyle J. and Robert Yager. "The University of Iowa Science and Culture Project," _School Science and Mathematics_, Vol. LXVI, No. 9, Whole 587, (May, 1968), 412-415.

Collins, Robert. "A Hard Look at Traditional Science," _Minnesota Journal of Education_, Vol. 45, (April, 1965), 29-30.

"Crisis in Education, Part I," _Life_, Vol. 44, No. 12, (Mar. 24, 1958), 27-35.

"Crisis in Education, Part II," _Life_, Vol. 44, No. 13, (Mar. 31, 1958), 93-101.

"Crisis in Education, Part III," _Life_, Vol. 44, No. 14, (Apr. 7, 1958), 89-96.

"Crisis in Education, Part IV," _Life_, Vol. 44, No. 15, (Apr. 14, 1958), 117-125.

Derthick, L. C. "The Frightening Challenge of Russian Schools," _Look_, Vol. 22, No. 21, (Oct. 14, 1957), 38-41.

Dubos, Rene' J. "Science in Human Affairs," _The Science Teacher_, Vol. 34, No. 5, (May, 1967), 11-12.

Gatewood, Claude. "The Science Curriculum Viewed Nationally," _The Science Teacher_, Vol. 35, No. 8, (Nov., 1968), 18-21.

Haber-Schaim, Uri. "IPS Second Edition," _Introductory Physical Science Newsletter_, (Spring, 1972), 1-3.

Hazlett, Henry. "Wake Up The Educators," _Newsweek_, Vol. L., No. 22, (Nov. 25, 1957), 111.

Hunter, George W., and Leroy Spore. "The Objectives of Science in the Secondary Schools of the United States," _School Science and Mathematics_, No. 43, (Oct., 1943), 633-647.

Hutchinson, Eric. "Science: A Component of Liberal Education," _Journal of Chemical Education_, Vol. 44, No. 5, (May, 1967), 261-269.

Keohane, Kevin W. "Toward an Integrated Teaching of the Sciences," _The Science Teacher_, (Oct., 1968), 39-43.

Kimball, Merritt E. "Understanding the Nature of Science: A Comparison of Scientists and Science Teachers," The Journal of Research in Science Teaching, Vol. 5, Issue 2, (1967-1968), 110-119.

Kline, Morris. "The Liberal Education Values of Science," The Science Teacher, Vol. 32, No. 8, (Nov., 1965), 22-24.

Kohler, Foy D. "The Non-Scientist Speaks on Science for a Liberal Education," The Science Teacher, Vol. 35, No. 4, (April, 1968), 12-14.

Lunetta, Vincent N. "Science and Man," The Science Teacher, Vol. 35, No. 7, (Oct., 1968), 33-35.

McCurdy, Donald W. "Has the National Science Foundation Widened the Gaps in Science Education Among Urban, Suburban and Rural Schools?" Science Education, Vol. 52, No. 4, (Oct., 1968), 368-371.

Newton, David E. "The Role of Science in General High School Education," School Science and Mathematics, Vol. LXIV, No. 6, Whole 566, (June, 1946), 550-552.

Pella, Milton O. "Scientific Literacy and the H. S. Curriculum," School Science and Mathematics, Vol. LXVII, No. 4, Whole 591, (April, 1967), 346-356.

"Physics Education Crisis," School and Society, Vol. 92. No. 2247, (Oct. 17, 1964), 301-305.

Piltz, Albert. "National Defense Education Act," Science and Children, Vol. 2, No. 7, (April, 1965), 9-11.

Sonneborn, Tracy M. "Secondary School Preparation for Making Biological Decisions," National Association of Secondary School Principals Bulletin, Vol. 56, No. 360, (Jan., 1972), 1-12.

Tompkins, Ellsworth. "An Odyssey Among the Projects," NASSP Spotlight, No. 67, (Mar.-Apr., 1965), 1-4.

Troxel, V. A. and R. E. Yaeger. "The Science Curriculum Effects Enrollments in Science?" School Science and Mathematics, Vol. LXVIII, No. 6, (June, 1968), 512-514.

U. S. News and World Report, Vol. XLIII, No. 21, (Nov. 22, 1957), 114-117.

Watson, Fletcher G. "Teaching Science to the Average Pupil," The Science Teacher, Vol. 34, No. 3, (March, 1967), 25-26, 81.

Wise, Harold E. "Science and Civic Responsibility," Science Education, Vol. 49, No. 3, (April, 1965), 196-205.

D. UNPUBLISHED MATERIALS

Baxter, Kendall Wight. "A Comparative Study of the Effectiveness of Three Methods of Teaching a General Education Physical Science Course." Unpublished Doctoral Thesis, Colorado State College, Greeley, Colorado, 1968.

Brouillette, Oscar Jason. "An Interdisciplinary Comparison of the Critical Thinking Objective Among Science and Non-Science Majors in Higher Education." Unpublished Doctoral Thesis, University of Southern Mississippi, Hattiesburg, Mississippi, 1968.

Korth, Willard William. "The Use of the History of Science to Promote Student Understanding of the Social Aspects of Science." Unpublished Doctoral Thesis, Stanford University, Palo Alto, California, 1968.

Mason, John M. "An Experimental Study in the Teaching of Scientific Thinking in Biological Science at the College Level." Unpublished Doctoral Dissertation, Michigan State College of Agriculture and Applied Science, East Lansing, 1951.

Sherman, Jack Eugene. "The Relative Effectiveness of Two Methods of Utilizing Laboratory-Type Activities in Teaching Physical Science." Unpublished Doctoral Thesis, University of Wisconsin, Madison, June, 1969.

Tanner, Richard Thomas. "Expository-Deductive versus Discovery-Inductive Programming of Physical Science Principles." Unpublished Doctoral Thesis, Stanford University, Palo Alto, California, 1968.

APPENDIX A

THE VOS OPINION POLL

APPENDIX A

VOS OPINION POLL

Directions: This is an opinion poll, not a test. Each item consists of a series of four events which are listed as (a), (b), (c) or (d). Your job is to read the description of all four events, and then attempt to rank these events in order of their value to civilization. Rank as first the event which, in your opinion, has done the most to make life better for the most people. Rank as second and third the next most valuable events. Rank as last the event which, in your opinion, has done the least toward making life better for the most people. Be sure to consider what each event has led to when you evaluate it. For example, if the event, "The first metal nail is manufactured," is listed, you should consider the general, overall effect that the use of metal nails has had rather than simply considering the value of the first nail.

1. (a) The safety pin is invented.

   (b) The East and West coasts of the United States are connected by rail for the first time at Promontory Point in Utah.

   (c) Night baseball is played for the first time.

   (d) Scientists study the phenomena of melting and freezing.

---

2. (a) Engineers complete construction of the Golden Gate Bridge.

   (b) Chemists learn how to measure the melting point of solids.

   (c) Work is completed on the Empire State Building.

   (d) Scientists learn how to convert heat energy into motion.

---

3. (a) Scientists learn how to use fractional distillation to separate one or more liquids from a mixture.

   (b) An Austrian monk crosses garden pea plants and makes a mathematical study of the kind of off-spring produced by the cross.

   (c) The four-cycle engine is invented.

   (d) The planet Pluto is discovered by astronomers.

---

4. (a) Scientists and engineers launch the first earth satellite, Sputnik.

   (b) The Olympics are renewed and a large number of countries take part in them.

   (c) Chemists find that some solids are more soluble in hot water than in cold water.

   (d) Eli Whitney invents the cotton gin.

---

5. (a) Robert Koch studies anthrax in sheep.

   (b) Scientists learn what makes it rain.

   (c) Engineers invent the transistor.

   (d) All elements are found to produce a characteristic spectrum which enables chemists to identify them.

---

6. (a) Scientists learn that the metallic elements have lower ionization potentials than do other elements.

   (b) The first night football game is played.

   (c) Scientists learn that some solids are more soluble in one liquid than in another.

   (d) The first rock and roll record is cut.

---

7. (a) Scientists learn how wheat rust is spread from one wheat field to another.

   (b) The earth's diameter is estimated to be approximately 3,000 miles.

   (c) The relationship density = mass or weight/volume is recognized.

(d) Scientists gain an understanding of air pressure.

---

8. (a) Chemists learn how to separate two substances from a liquid mixture by the process of fractional crystallization.

(b) The steam engine is perfected.

(c) The first typewriter is patented.

(d) Millikan performs an experiment which reveals the electrical charge carried by an electron.

---

9. (a) Abraham Lincoln is elected President of the United States.

(b) Scientists learn how to measure the solubility of solids in certain liquids.

(c) Jack London writes <u>Call of the Wild</u>.

(d) Gold is discovered at Sutter's Mill in California.

---

10. (a) Talking motion pictures are perfected and shown to the public.

(b) The ball-point pen is invented.

(c) The Chicago Cubs win the World Series.

(d) It is discovered that certain substances are more soluble in one liquid than in another.

---

11. (a) The laws of optics are discovered.

(b) Scientists learn how to separate solids from a mixture by taking advantage of differences in their solubility.

(c) Engineers complete construction of the Panama Canal.

(d) Galileo simultaneously drops heavy and light objects from a height and finds that both objects fall at the same speed.

---

12. (a) An English scientist discovers that when a bar magnet is thrust into a coil of wire, a feeble surge of electrical current is produced.

(b) Scientists discover that all substances have certain characteristic properties which make their identification possible.

(c) The wireless telegraph is invented.

(d) The first hockey game is played.

APPENDIX B

ACTIVITIES EMPLOYED WITH THE TREATMENT GROUP

APPENDIX B

ACTIVITIES EMPLOYED WITH

THE TREATMENT GROUP

This appendix contains a brief description of the activities carried on by the treatment group. Although the time required for each activity varied from class to class, an approximate time schedule has been included. The complete time required for an activity is shown as a solid block, but in many instances, it was necessary, or pedagogically better, to extend some of these activities over two periods or otherwise break them up.

45 minutes - Administration of VOS Opinion Poll.

10 minutes - Students read section 1.0.

30 minutes - Students observe mosquito larvae and pupae in an aquarium and look at prepared slides of malaria parasites at various stages in their life cycle.

30 minutes - Discussion of section 1.0.

5 minutes - Assignment of projects listed under "Things to do" section. (There are approximately forty project-type activities of various length scattered throughout the reading material. Some projects require several hours or more for completion.)

35 minutes - Students read sections 1.1-1.7.

30 minutes - Discussion of sections 1.1-1.7.

30 minutes - Project reports and assignment of projects.

30 minutes - View film, "Unseen Enemies." (Excellent film dealing with world health problems including malaria.)

20 minutes - Discussion of film.

30 minutes - Students read sections 1.8-1.10.

30 minutes - Discussion of sections 1.8-1.10.

30 minutes - Project reports and assignment of projects.

30 minutes - Students learn how to prepare permanent slides of mosquito appendages using Canadian Balsam.

45 minutes - Students read sections 1.11-1.13.

40 minutes - Discussion of sections 1.11-1.13. (A sealed five gallon bottle aquarium complete with plants and small fish when compared to the planet Earth makes a provocative starting point for a discussion.)

30 minutes - Project reports and assignment of projects.

30 minutes - View film, "Rival World." (Excellent film dealing with threat posed by insects and problems associated with their control.)

30 minutes - Discussion of film.

30 minutes - Students read sections 1.14 and 1.15.

30 minutes - Discussion of sections 1.14 and 1.15.

30 minutes - Project reports and assignment of projects.

50 minutes - Students make models of various molecules using styrofoam spheres and toothpicks. (Spheres of several colors and sizes are required.)

30 minutes - Final report on projects.

40 minutes - Test over work covered thus far.

20 minutes - Discussion of test.

10 minutes - Introduction to the second part of the unit.

30 minutes - Students read sections 2.0 and 2.1.

20 minutes - Superficial discussion of reading material.

240 minutes - Students learn how to carry out separation techniques in the laboratory as described in the reading materials. Part I, filtration techniques, requires about 50 minutes, including a brief pre- and post-lab discussion. Part II, use of the separatory funnel requires about 20 minutes. Part III, fractional crystallization, requires 50 minutes or more. Part IV, the separation of the chlorides of sodium, lead, mercury and silver requires 60 minutes. Part V, the distillation of an alcohol-water mixture requires 60 minutes.

40 minutes - Students do "Questions and Problems" following section 2.1.

30 minutes - Discussion of items assigned.

10 minutes - Review and overview of unit. Periodically, students were reminded of the point to the laboratory work. The following "flow sheet" proved valuable:

Mankind learns that a naturally occurring material contains a medically valuable substance. (i.e., cinchona bark contains quinine)	(humanistically-oriented materials Sections 1.0-1.15)
Next, ⇩	
Chemists separate the medically valuable substance from the material in which it occurs. (This is done by filtration, fractional crystallization, distillation, etc.)	(Sections 2.0-2.1)
Next, ⇩	
Chemists study the physical properties of the medically-valuable substance so that they can identify or duplicate it. (The density and melting point of the substance are determined.)	(Section 2.2)
Next Step ⇩	

As each new section is covered, this flow sheet may be extended. If this is done, it may help the student to attach some value to his laboratory work, because they can see how this work has been of value to civilization.

20 minutes - Students read section 2.2.

50 minutes - Students make laboratory determinations of the densities of various substances.

50 minutes - Students make laboratory determinations of the melting point of various substances.

20 minutes - Review density calculations.

30 minutes - Students do "Questions and Problems," section 2.2.

20 minutes - Discussion of previous assignment.

20 minutes - Quiz over sections 2.0-2.2.

20 minutes - Discussion of quiz.

40 minutes - Students read section 2.3.

20 minutes - Discussion of reading.

60 minutes - Students learn how to analyze an unknown for the presence of lead, mercury and silver.

60 minutes - Students analyze several unknowns for the presence of lead, mercury and silver.

30 minutes - Students do "Questions and Problems" following section 2.3.

30 minutes - Discussion of previous assignment.

20 minutes - Quiz over section 2.3.

50 minutes - Students read section 2.4. (Much of this section is too difficult for low students and was simplified for this group.)

20 minutes - Discussion of reading.

50 minutes - Students synthesize zinc chloride in the laboratory and determine its formula. (While many low level students have difficulty with the arithmetic associated with this experiment, they can follow the procedure when someone else performs it. For our purposes, this is all that is necessary.)

50 minutes - Students do items selected from "Questions and Problems," section 2.4.

30 minutes - Discussion of items assigned previously.

15 minutes - Overview, review of unit using extended flow sheet.

15 minutes - Quiz on extended flow sheet.

40 minutes - Students collect laboratory data enabling them to plot a freezing point curve for naphthalene.

50 minutes - Students collect laboratory data enabling them to plot a freezing point curve for solutions of various concentrations of sulfur in naphthalene. (From this data it is possible to develop the idea that the freezing point of a solution depends on the number of solute molecules present. Low students require much help with the mathematics required.)

35 minutes - Students read section 2.5. (More difficult sections were deleted for slower classes.)

30 minutes - Discussion of reading.

50 minutes - Students do selected items from "Questions and Problems," section 2.5. (Again, more difficult items were deleted for slower classes.)

30 minutes - Discussion of previous assignment.

15 minutes - Review of unit using extended flow sheet.

20 minutes - Students read section 2.6.

20 minutes - Discussion of reading.

60 minutes - Students carry out laboratory activities designed to illustrate that alkane and alkene families have characteristic, but different, chemical properties.

60 minutes - Students do "Questions and Problems," section 2.6.

30 minutes - Discussion of assigned items.

20 minutes - Quiz over section 2.6.

10 minutes - Students read section 2.7.

10 minutes - Discussion of reading.

40 minutes - Students were given fragments of molecular models and were asked to assemble the fragments in accord with information supplied them. (This activity attempts to duplicate the chemist's mental reconstruction of a molecule following chemical degradation.)

40 minutes - Students do "Questions and Problems," section 2.7.

30 minutes - Discussion of previous assignment.

35 minutes - Students read section 2.8.

20 minutes - Discussion of reading.

60 minutes - Students carry out selected syntheses in the laboratory. (Traditional syntheses such as soap making and the Tollen's silver mirror test were employed.)

30 minutes - Discussion of the synthesis of organic compounds. (The flow sheet shown in the reading material should be treated as a "road map" rather than asking students to memorize all of the reactions shown.)

40 minutes - Students do selected items from section 2.8 Questions and Problems.

30 minutes - Discussion of assigned items.

20 minutes - Quiz over section 2.8.

10 minutes - Students read section 2.9.

30 minutes - Discussion of reading.

20 minutes - Students do items in 2.9 Questions and Problems.

20 minutes - Discussion of assigned items.

10 minutes - Students read section 2.10.

30 minutes - Discussion of reading.

20 minutes - Students do items in 2.10 Questions and Problems.

30 minutes - Discussion of assigned items.

45 minutes - Administration of VOS Opinion Poll.

40 minutes - Written examination over entire unit.

APPENDIX C

THE HUMANISTICALLY-ORIENTED SCIENCE CURRICULUM MATERIALS USED TO INSTRUCT THE TREATMENT GROUP

APPENDIX C

THE HUMANISTICALLY-ORIENTED SCIENCE CURRICULUM MATERIALS USED TO INSTRUCT THE TREATMENT GROUP

PART I

An Overview of This Section

This section is devoted to the presentation of reading materials for a humanistically-oriented science course.[1] Although these reading materials deal with many of the same topics which are normally dealt with in either traditional or process-oriented science courses, these materials make a greater effort to place the subject matter in a social or cultural setting and to illustrate the contribution the subject matter can make toward improving man's life. Since this section is concerned with "setting the stage" for the more technical material which follows in the next section, it will contain more historical and less scientific subject matter than either traditional or process-oriented science courses.

Reading Materials for a Humanistically-Oriented Science Course

On the Trail of Mankind's Greatest Killer

(The story which you are about to read is essentially true. The names are fictitious, but events like those described have taken place. The time is 1940. The setting is an ancient Indian Village several hundred miles from Mexico City. Many of the people who live here still speak the

[1]Certain illustrations which appeared in the original materials have been deleted because of difficulties encountered in reproduction.

Indian dialect that was spoken here before the coming of the Spanish Conquistadores. Few of the villagers can read or write; superstition is widespread. Almost everyone in the village makes their living by farming, and the simple one-room adobe huts that they live in contain little furniture or other material goods.)

1.0 The Farmer and the Mosquito

When the clock in the plaza struck five, Juan Chavez arose. His wife had already been up for more than an hour, and she had a breakfast of tea, tortillas, and chile ready for him. While he ate, his wife filled a hollowed-out gourd with tea, and a hemp bag with his lunch. A half-hour later, Juan was on the way to his fields. He walked down the rutted road, past the church in the plaza, and headed out of the village. An hour later, Juan reached his fields.

Earlier in the summer, Juan had planted corn, and now it was higher than it ever had been before at this time. Never had growing conditions been better; with each passing day the corn neared maturity.

Throughout the day, as he weeded between the corn plants, Juan thought: This year I shall pay off my debt to Don Gomez. For as long as Juan could remember, he had owed money to Don Gomez, the money-lender. Each year, after the harvest, Juan had paid what he owed; but before the next harvest, he had been forced to reborrow the money. It simply took an unbelievably large crop to pay the debt and keep his family fed until the next harvest. With the promise of this year's exceptional crop, Juan thought that he might be able to pay his debt.

Much later in the day, when the corn cast a shadow that was longer than its height, Juan left his fields. Tired, but happy, Juan walked down the mountain road. The day had been hot, and he had finished the tea that his wife had packed many hours earlier. The heat of the day, plus the chili and tortillas that he had for lunch, had made him very thirsty.

Soon Juan neared the stream which the villagers called "Los Aires," or "the spirits of the air." Juan, like most of the villagers, believed that this stream contained spirits who could cause sickness or bad times to befall those who offended them. When farmers who were going to their fields walked past the stream, they pulled their blankets a little tighter about them and walked on the far side of the road. Today, however, Juan was very thirsty: so, after wrapping his blanket tightly about himself, he knelt beside the stream and filled the gourd that had held tea earlier in the day. Ordinarily, as a precaution against the spirits, Juan would have asked for permission from the stream before taking the water; but today, the danger posed by the spirits was simply not foremost in Juan's mind.

Weeks earlier, the same stream had a different visitor, Anopheles aztecus. Flying low over the bank of the stream, Anopheles aztecus had located a place where aquatic vegetation sharply curtailed the flow of water. There, in the nearly stagnant water, she laid nearly 200 eggs. Each egg floated by itself on the surface of the water.

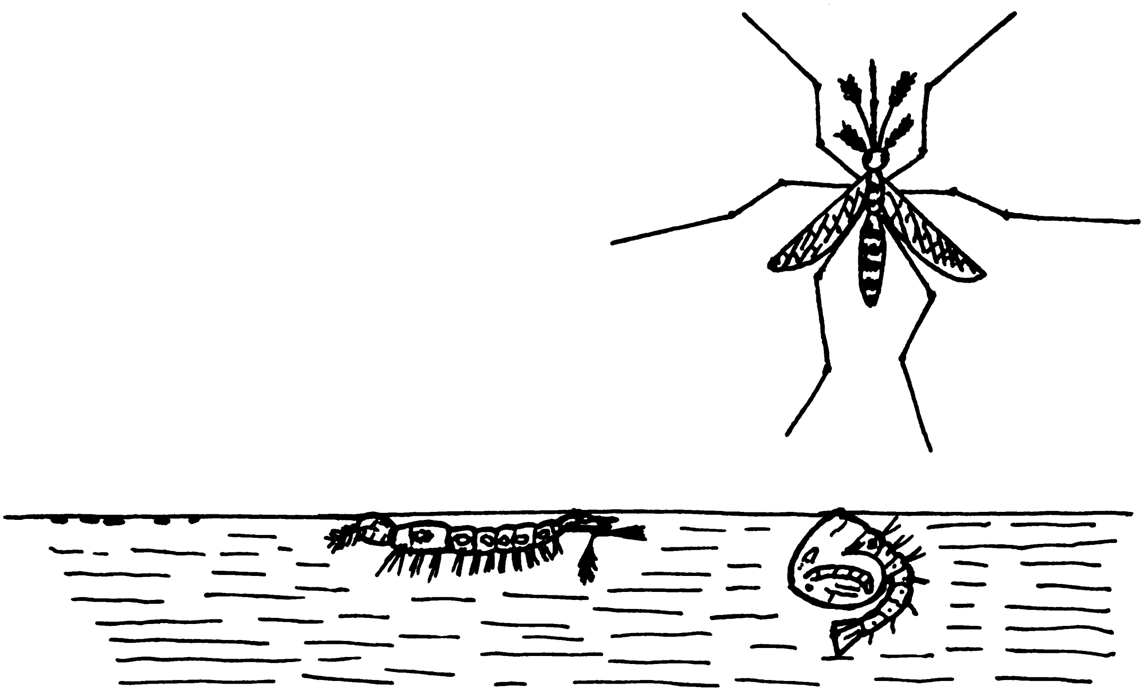


Figure 1. The life cycle of the mosquito, Anopheles aztecus. The eggs appear at the left. The wriggler, or larval stage, appears in the center. The mummy-like pupal stage is shown at the far right, and the mature adult is shown at the upper right.

Forty-eight hours later, the eggs hatched and minute wiggling creatures emerged. In a short time, these wrigglers had suspended themselves just beneath the water's surface. So that they might breathe from the air, each wriggler thrust appendages called respiratory discs above the surface of the water. At the same time, they began

feeding voraciously by sweeping the water with brushes which were attached to their mouth parts. Feeding continuously, the wrigglers were able to strain out fantastic quantities of algae and bacteria. They grew so fast that they outgrew and shed their skin three times in only a week. After the third molt, the wrigglers began to curl up into a shrimp-like figure. Soon, they floated like tiny grotesque mummies just beneath the surface of the water. Although this mummy-like stage did not feed, it could swim; and it did so whenever it became necessary for it to escape from the numerous fish who fed upon it.

Two days after it had formed, a crack appeared in the back of the mummy-like case. Through this crack an adult mosquito emerged. The insect balanced briefly on the remains of the mummy-like case, spread its wings, and then flew to the stream bank.

Each day at dusk, the young mosquitoes came out to feed. While the male mosquitoes were content to suck plant juices, the females required a meal of blood.

Juan rested on one knee at the edge of the stream. He drank from the hollowed-out gourd which he had just filled from the stream. So intent on this pleasure was Juan, that Anopheles aztecus was able to land on his ankle without being noticed.

Using one of the many appendages on its head, Anopheles aztecus probed, looking for a patch of skin which was soft enough to puncture. As soon as it had found a soft place, Anopheles aztecus used its grooved lower lip to guide six sharp, hollow, needle-like tubes to this site. Through one of these tubes flowed saliva. The saliva contained an anticoagulant which prevented Juan's blood from clotting before the mosquito had finished its meal.

Had Anopheles aztecus' saliva contained only the anticoagulant described, Juan's life probably would have gone on unchanged. However, sometime during the summer, this particular mosquito had bitten someone whose bloodstream contained the microscopic organism Plasmodium vivax.

As the mosquito had withdrawn its meal of blood, many of these tiny organisms had accompanied it. Once in the mosquito's stomach, Plasmodium vivax had mated, burrowed into the mosquito's stomach wall, and formed a capsule-like structure. Two weeks later, the now mature capsule had burst, releasing a new form of Plasmodium vivax into the mosquito's body cavity. Now fully 200,000 strong, Plasmodium vivax gathered in the mosquito's salivary gland.

As the mosquito bit Juan, over 20,000 Plasmodium vivax organisms were in the drop of saliva which flowed downward into the small puncture which had been made. Most of these organisms entered Juan's bloodstream. Juan swatted absent-mindedly at the point of irritation, crushing the fragile mosquito. He rose and walked down the dusty, rutted road toward home. Juan was completely unaware of the thousands of Plasmodium vivax organisms which swarmed about in his bloodstream.

An organism, such as Plasmodium vivax, which gains its living at the expense of another organism is known as a parasite. Throughout history, Plasmodium vivax has proven to be one of the worst parasites with which man must contend. In the 1940s, one-half of all of the deaths in the world were caused by Plasmodium vivax or other closely related organisms. However, Juan knew none of these things. As he walked home, he thought only of his beautiful corn and of the fact that finally, after many years, he would soon be free of debt.

Within thirty minutes after their entry into Juan's body, no parasites were to be found in his bloodstream; mysteriously, they had vanished. Seven days later, after two changes of form, the parasites left the cells of the liver where they had been hiding. They re-entered the bloodstream and began to attack red blood cells. At this stage, Plasmodium vivax looked like a microscopic signet ring; circular in shape, the center of the parasite was a transparent bubble. At one edge, a dark, stone-like nucleus was apparent.

Each parasite burrowed into a red blood cell. Once inside the blood cell, the parasite began to feed. As the parasite fed, its nucleus split in two. Then, it divided again and again. Forty-eight hours later, the dying red blood cell burst, and ten to twenty newly formed parasites emerged. Each of these parasites promptly attacked a new red blood cell. The pigments and waste products, which had been left behind in the dead red blood cell, drifted about in the bloodstream. Later, these fragments would be deposited in the spleen, or under the skin, giving it a yellowish cast.

While most of these things had been going on, Juan had felt nothing. He had cultivated his corn and made plans to enjoy a religious holiday after the harvest. However, when the Plasmodium vivax parasites had burst from the red blood cells upon which they had been feeding, Juan became acutely aware that something was definitely wrong.

Tired from his long day in the field, Juan had gone to bed about nine. Shortly after midnight, he had awakened.

Even though the night was not cold, he shivered and shook; never, even in the middle of winter, had he ever been colder. Juan insisted that his wife build a huge fire. After this had been done, he tried to get out of bed so that he could sit in front of the fire. However, when he stood up, waves of dizziness swept over him and the floor seemed to tilt. He sat back down on the bed and continued to shiver and shake; his teeth chattered loudly.

Throughout the hours that followed, Juan's chill became so severe that the entire bed shook. He became delirious and thrashed about in the bed. To his wife, it appeared as though Juan was possessed by demons.

All the time that Juan was chilling and shivering, his temperature was going up. Finally it peaked at 105°F, almost 7°F above normal. With this burning fever came complete weakness, nausea, and violent headache. Then, the chills stopped and Juan was overcome by a dry, burning heat; his skin felt as though someone had built a fire beneath the bed. Juan became unbelievably dry and thirsty; it seemed impossible for him to swallow.

Later, as the fever began to subside, Juan began to sweat profusely. Both his own clothing and the straw-filled mattress became soaking-wet. By eight o-clock the next morning, seven and one-half hours after the onset of the attack, Juan was resting quietly. He felt more dead than alive.

Not until evening, almost twenty hours after the onset of the first chills, did Juan begin to regain his strength. The next day Juan got up and walked weakly around the adobe hut. Tomorrow he would go to work in the fields, he said.

After the evening meal, of which Juan partook sparingly, he went to bed. He still felt weak, and he would need all of his strength for the coming day's work, he told his wife. However, just after midnight, Juan was again awakened by a terrible chill. In the next eight hours that followed, Juan experienced exactly the same ordeal that he had suffered through two days previously.

For two weeks, Juan had similar feverish attacks every other day. On the day following an attack, he was simply too weak to even walk to his fields, let alone work in them. After the second attack, both Juan and his wife had agreed that the spirits of the air, Los Aires, were the cause of Juan's attacks. It was obvious that he had incurred their wrath by taking water from the stream without first asking permission. Convinced of this, Juan's wife made no attempt to get a doctor.

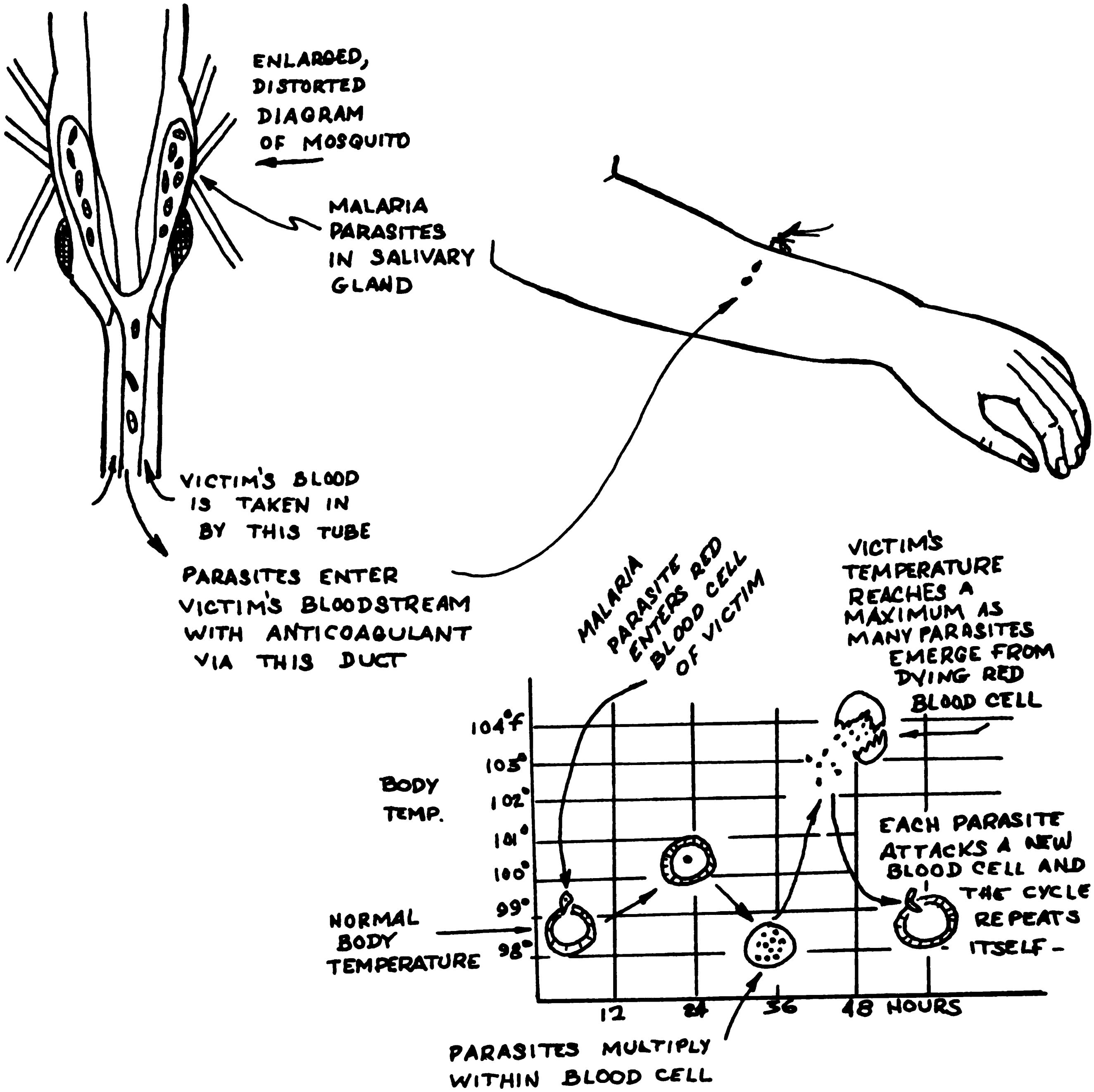


Figure 2. The life cycle of the malaria parasite, Plasmodium vivax. The graph at the lower right shows the correlation between the body temperature of the victim and that part of the life cycle of the parasite which takes place in the human red blood cells.

Until the mid-1930s, many of those who lived in the isolated rural areas had never seen a doctor. Few doctors wished to live in the bush; there were few conveniences, and they felt rejected by the deeply superstitious people whom they were trying to help. In 1936, the Mexican government attempted to remedy this situation by assigning medical students to rural areas for a period of several months prior to their graduation. Even an inexperienced medical student would have instantly identified Juan's illness as malaria. Juan had all the classic symptoms of malaria: the periodic chills, the high fever, a yellowish cast to his skin, an enlarged spleen and anemia.

At the age of 50, Juan was, as rural farmers go, a worn-out old man. Had a doctor seen Juan, he would have instantly given him quinine. This drug had proven its worth since the 1600s, and it might have saved Juan, as it had saved millions of others. As it was, Juan had grown weaker with each successive attack. The destruction of red blood cells by the malaria parasites had left Juan more and more anemic. Sometime during the night of the eighth attack, Juan died. The corn, whose sale was to have taken Juan out of debt, was instead sold to pay for his funeral.

1.0 Things to Do

1. The farmer in the story, Juan Chavez, is poor. What percentage of the earth's people would you guess spend their lives on a similar economic level? Can the manner in which these people live have a bearing on your life?

2. Describe the life cycle of the mosquito Anopheles aztecus. Why is it important that mankind has knowledge of the life cycle of mosquitoes?

3. Make a series of drawings which shows the life cycle of a typical mosquito. If possible, make your drawings from living mosquitoes.

4. Collect different kinds of mosquitoes. Is it easy to tell one kind from another?

5. How do you suppose that the superstitution that streams could house "evil spirits" got started?

6. Is malaria a health problem in your area? Was it ever a health problem here?

1.1 A Brief History of Malaria: Malaria and the Early Civilizations

Malaria has probably afflicted mankind for thousands of years. Two thousand years ago, Rome was the dominant country on earth; its empire extended from England to Egypt. However, despite the military might of the Romans, malaria became so firmly intrenched in the mosquitoes of the Pontine Marsh just outside of Rome, that no one was able to live there until the present century. Historians now believe that mosquitoes from the Pontine Marsh may have helped to spread malaria throughout the city of Rome, disabling the people, and thus hastening the decline and subsequent fall of the Roman Empire. In similar fashion, malaria may have played a role in the fall of the Greek city-states. Although we cannot be certain of the exact extent of the role malaria played in the fall of Greece or Rome, it is quite possible that the present ruins of these civilizations stand as great monuments to the fact that neither Greeks nor Romans were able to cope with malaria.

It is worth noting that the name "malaria" is Roman, or Latin, in origin. The prefix "mal" means "bad," and the suffix "aria" means "air"; hence, malaria meant "bad air" to the Romans. This name also indicates what the Romans thought to be the cause of malaria. For centuries after the Romans, many people still thought that night air was "bad" and could cause malaria. As you may recall, this feeling was expressed by the villagers in our previous story: The spirits of Los Aires were "the spirits of the air."

1.1 Things to Do

1. Have diseases other than malaria had an effect on the course of civilization? If this question sounds interesting to you, you might enjoy reading The Plague Killers, by Greer Williams, or Microbe Hunters by Paul de Kruif.

2. In the mid-1800s, Napoleon's Grand Army of 500,000 men invaded Russia. Months later, only 30,000 ragged survivors straggled out of Russia. Few major battles had been fought, and Napoleon's worst enemy had been typhus fever. How is typhus fever spread? In the past, has it been an important disease?

1.2 Malaria During the 1800s

Today we think of malaria as a tropical disease, but the fact is that less than 100 years ago, malaria was very widespread. When the Louisiana Purchase brought us the western half of the Mississippi Valley in 1802, the territory acquired was described as "one huge malaria-infected swamp."

Figure 3. The worldwide distribution of malaria. The shaded areas on this map indicate the presence of malaria at the beginning of the present century.

During the American Civil War, the Northern army under General McClellan drove to the banks of the Chicahominy River, only seven miles from the Confederate Capitol. There, only miles short of his goal, McClellan stopped, his ranks thinned by "Chicahominy Fever," or malaria. It was not uncommon for some Northern regiments fighting in the deep South to average four malaria attacks per man. Although the South was more accustomed to malaria, it also was forced to contend with the disease, of course.

Malaria also troubled other northern countries. From 1850 to 1860, one out of every twenty London hospital beds was occupied by a victim of malaria. Farther south, in Italy, malaria was the number one health problem at the beginning of the present century.

1.2 Things to Do

1. Consult local health authorities or records to find out which diseases have been serious problems in your area in the past.

2. It is often said that, "The mosquito is the most dangerous animal alive." Carry out library research which will support or refute this statement.

1.3 Malaria and the Panama Canal

In 1883, the French began excavation of a 52 mile channel across the tropical Isthmus of Panama. When completed, this channel would link the Atlantic and Pacific Oceans; it would cut thousands of miles from an ocean voyage which once had forced ships to navigate the rough waters off the southern tip of South America. Six years later, however, the French abandoned the project. At the construction site, they left thousands of dollars of earth moving machinery to rust in the hot, moist tropical air. They also left behind almost 50,000 newly-filled graves. It was said that one could have buried a Frenchman beneath each tie of the 52 mile long railroad which transversed the Isthmus. Most of these deaths were due to malaria or another mosquito-spread disease, yellow fever.

In 1904, the U. S. sought to complete the project. Less than a year later, the serious threat posed by malaria and yellow fever became apparent. In the interim between the French and American attempt, scientists had discovered that both diseases were spread by mosquitoes. Laborers were taken from the canal and set to work draining and poisoning swamps. As their breeding places were destroyed, the number of mosquitoes decreased sharply, and malaria and yellow fever ceased to claim their frightful toll. In less than ten years time, in nearby Havana, Cuba, malaria diminished from 901 cases per 1000 people to only 19 cases per 1000 people per year.

1.3 Things to Do

1. How did knowledge of the life cycle of the mosquito help the Americans to fight malaria and yellow fever in Panama?

2. Why were the Americans better able to control malaria and yellow fever than the French?

1.4 The Conquest of Malaria in the U. S.

As the U. S. entered the present century, the spectre of malaria posed a grim threat to most of the southern part of the U. S. Malaria was especially dangerous to the poor who were unable to afford good medical treatment. It weakened and disabled thousands of tenant farmers and factory workers. Malaria came on with the appearance of the first mosquitoes in April and lasted until the first hard frost in the fall.

With the help of the Rockefeller Foundation, Southern communities began to wage war on the malaria-carrying mosquito. During 1912, numerous programs of habitat destruction were initiated in several states. In most of these programs, standing water was drained or sprayed with kerosene. Next, pyrethrum, which had been found to be an effective insecticide, was sprayed in houses. Malaria victims were given quinine, which helps to control the malarial parasite itself.

By 1923, the attack on malaria had been extended to 15 states. Only four years later, in 1927, malaria was a thing of the past in almost all U. S. towns and cities. However, almost 20 years would pass before malaria would be eradicated from all of rural United States. As late as 1935, the U. S. still had 900,000 cases and 4,000 deaths from malaria each year.

1.4 Things to Do

1. To determine how serious a problem malaria actually was in the U. S., try to find out the following facts: (a) the number of cases of malaria in a given year; (b) the number of deaths during this year; and (c) the U. S. population during the same year. Next, try to determine the same facts for any one of the serious diseases which presently trouble the U. S. How does the seriousness of malaria compare with the disease selected?

2. The Rockefeller Foundation has long played a positive role in the conquest of many diseases. What diseases is this Foundation presently helping to combat?

1.5 Malaria During the 1900s

During the early decades of the current century, many other countries also had trouble with malaria. By 1914, malaria was generally acknowledged to be the world's number one health problem. In India, malaria had long been known as "the king of disease." During World War I, Allied and German Armies fought each other in the Balkans where malaria had long been entrenched. Throughout the entire campaign, both armies were forced to maintain huge field hospitals to treat thousands of malaria victims. Malaria often claimed more victims than did gunfire.

In 1922, two million Italians--one out of every twenty--had malaria. One year later, in 1923, Russia, which was already beset with typhus fever and famine, suffered 18 million cases of malaria.

The worst malaria epidemic that the North or South American Continent has ever seen began in 1938. Seven years earlier, malaria-carrying Anopheles mosquitoes had been accidentally transported by French war-ships from French West Africa to Brazil. Once off the boats, the mosquitoes spread up and down the coast. In 1938, malaria burst out all along the mosquito-infected Brazilian coast. Over 100,000 cases of malaria were reported and at least 20,000 people died. Malaria touched almost every family in the area.

1.5 Things to Do

1. Select any one country and see what you can find out about the present or past effect of malaria in this country.

2. Try to estimate the total number of deaths due to malaria. Base your estimate on the facts which you can find rather than simply making an unsupported guess.

1.6 Malaria During World War II

On December 7, 1941, the U. S. was plunged into a war which was to be fought in the tropical South Pacific where malaria had long been a scourge. Malaria quickly became the number one infectious disease among troops stationed in this area. In the early stages of the New Guinea campaign, there were half-a-dozen malaria victims for each casualty in battle. General Douglas MacArthur, Commander-in-Chief in the South Pacific region, was quoted as saying that for each division in the field, he had two divisions in the hospital or convalescing from malaria. In all, during World War II, there were 377,994 cases of malaria in the U. S. armed forces.

World War II marked the beginning of all-out chemical warfare against both the Anopheles mosquito and the malaria parasite. For the first time, such potent weapons as dichloro-diphenyl-trichloroethane (DDT), atabrine, and chloroquine were used. Until the advent of DDT, mankind had no really practical way of killing adult mosquitoes out-of-doors. Mid-way through the war, in 1943, the U. S. Bureau of Entomology and Plant Quarantine showed that all of the adult mosquitoes in an acre of swamp land could be killed by spraying about three quarts of 5% DDT. Soon thereafter, army combat airplanes were adapted for spraying DDT over large areas; and malaria was first brought under control, and then virtually eliminated from much of the South Pacific.

The army's success with DDT, plus field tests at Tallahassee, Florida, Stuttgart, Arkansas, and other places, proved conclusively that DDT was the most effective known killer of adult mosquitoes.

1.6 Things to Do

1. It is frequently said that "disease kills more soldiers than cannon and sword." Carry out library research which will support--or refute--this statement.

2. Why do you suppose malaria was such a serious problem in the early stages of the war, and less serious a problem later in the war?

1.7 Malaria From the End of World War II to the Present

In 1948, the nations of the world joined together to form the World Health Organization (WHO). This group immediately placed malaria at the head of the list of health problems for which it would seek a solution. Seven years later, even though in the intervening years great strides had been made against malaria, WHO said:

> The truth is that malaria is a disaster, and its terrible consequences (among the third of the world's population which already has more than its fair share of disease and poverty) cannot be easily visualized in countries that are free of it.

WHO began to organize an army of 190,000 specialists and volunteers throughout the world to fight the disease. Using the same techniques which had proven so effective in the Stuttgart and Tallahassee field trials, WHO forces, working with government teams, scored an impressive number of triumphs against the disease. For example, in Ceylon, the use of DDT caused the death rate to fall almost 50%--from 22 to 12 persons per 1000--in only seven short years. Earlier, it had taken England 70 years to lower its death rate this much.

In the 1940s, there were 200 million cases of malaria per year. Approximately one person out of every six on earth had malaria. Yearly, over 3 million people died of malaria. The disease directly accounted for over one-half of all the deaths on earth. Since malaria is primarily a disabler rather than a killer, it probably played an indirect role in the death of many more people. With the help of DDT, by 1966, the death toll claimed by malaria had been reduced to about one-third of the 1940 figure. Originally, over one-half of the world's population had lived under the threat of malaria. After the use of DDT, 80% of these people lived in areas which had been freed of this threat.

Today, thanks largely to the chemical arsenal that was developed to fight malaria, the disease remains a serious problem only in those areas where man has not made consistent use of these chemicals over a prolonged period of time. Only in tropical Africa does conquest of the disease remain an unsolved puzzle.

In terms of the total number of people whose lives were affected, the conquest of malaria far surpasses man's earlier victories over bubonic plague, cholera, and typhoid fever.

1.7 Things to Do

1. Collect statistics which show that malaria has been a more serious health problem than bubonic plague, cholera or typhoid fever.

2. Take an informal poll among your family and friends who are not in this class to see how many people are aware of the fact that malaria was once the number one killer of men.

1.8 Man Discovers How Malaria is Spread

Two hundred and thirty years before mankind had any inkling that mosquitoes and malaria were related, Jan Swammerdam of Holland began to study mosquitoes. Later, others also studied the fragile, winged insects; but these early studies were usually confused collections of inaccuracies, because no one seemed able to distinguish one kind of mosquito from another. With over 2000 different species of mosquitoes, all of which looked somewhat alike, careful, systematic study of their body shape and appendages was necessary before such distinction could be made. The foundation for just such study was outlined by the Swedish botanist, Carolus Linnaeus, in 1735. Less than 100 years later, the carrier of malaria--the Anopheles mosquito--was described using the guidelines Linnaeus had developed. Although the fact that this mosquito carried malaria was still unknown, at least it was now possible to distinguish Anopheles from other kinds of mosquitoes.

Figure 4. The antennae of a variety of different kinds of mosquitoes. Seemingly unimportant studies must be carried out if man is to be able to proceed with the important business of distinguishing one species of mosquito from another.

As the 1800s ended, several persons studied the larval form of mosquitoes; from these studies came an understanding of the way in which mosquito larva breathe. By 1896, the life cycle of the Anopheles mosquito had been described in great detail. Five years later, the importance of the Anopheles mosquito in the spread of malaria had been recognized, and a large, complete book with many pages devoted to classifying mosquitoes was published. Now, man knew one of the antagonists which he'd have to control if he was to stop malaria.

Complete knowledge of the other antagonist, the malaria parasite, Plasmodium vivax, was also gained during the first years of the current century. In 1877, Patrick Manson saw microscopic filarial worms in the stomach of mosquitoes which had bitten humans suffering from elephantiasis. Although Manson was convinced that elephantiasis was caused by the filarial worms, he was unsure of the mosquito's role in the disease. At the time, Manson believed that humans contacted the disease by drinking water in which filarial infected mosquitoes had drowned. Today we know that elephantiasis is spread in exactly the same manner as malaria: The mosquito bites an infected person and withdraws its meal of blood, which also contains the parasite. Later, the same mosquito bites a healthy person and passes some of the filarial worms on to this person.

Three years later in 1880, a French Army doctor, Alphonse Laveran, was studying the blood of malaria victims, under a microscope. Intent on a group of red blood cells, Laveran saw the long, whip-like flagella of a malaria parasite extend itself from a red blood cell. Five years later, Golgi noticed that the red blood cells always ruptured and the parasites emerged at the same time as the onset of the chills which marked the beginning of a malaria attack. Following this discovery, two Italian scientists attempted to produce malaria in volunteers by injecting them with the blood of malaria victims. Something was missing, however, and these experiments failed. Seven years after this failure, at least one scientist guessed the reason: The malaria parasite must spend part of its life in some organism other than man. This guess was based on the previous failure to transmit malaria from sick to healthy people by direct injection and on what had recently been learned about another unrelated parasite, the coccidia, which also spends part of its life cycle in two different hosts.

Two years later, in 1894, Manson made the guess that some species of mosquito carried malaria. He discussed this theory with Ronald Ross, of the Indian Medical Service, who was on leave in England at the time. When Ross returned to India, he began to devise experiments to test Manson's theory. During the next two years, Ross doused volunteers with water in which mosquitoes had drowned, but none of the volunteers developed malaria. Next, he allowed mosquitoes to feed on malaria victims; however, when the same mosquitoes were subsequently allowed to bite volunteers, no malaria resulted. Ross, unaware that only Anopheles mosquitoes could carry malaria, had used Culex and Aedes mosquitoes in his tests. While visiting in the highly malarious Nilgiri Hill region, Ross noticed a different, spotted winged mosquito. Using this species of mosquito, Ross was able to transmit malaria to sparrows. Later, Manson's own son volunteered to act as a human guinea-pig: When bitten by a spotted winged mosquito which had previously dined on malaria victims, he developed malaria.

Meanwhile, in Italy, where Malaria was the number one health problem, Giovanni Grassi identified the spotted winged carrier of malaria as an Anopheles mosquito. Using funds supplied by the Italian Government, Grassi carried out an experiment which seemed to indicate that malaria must be spread by mosquitoes. In a malaria-infested area, Grassi selected two groups of peasants. One group slept in screened rooms and spent the evening hours inside screened buildings. The second group did not have screened sleeping quarters, nor did they spend the evening hours inside. During the hot summer which followed, only 5% of the screened group contacted malaria; almost 100% of the unscreened group were stricken. This experiment proved that malaria was spread by the mosquitoes present in the area.

After almost two hundred years of study, man had finally gained enough knowledge so that he could begin to mount an effective campaign against his greatest enemy. For the first time, the days in which mankind would be forced to live in fear of malaria appeared to be numbered.

1.8 Things to Do

1. Collect as many different kinds of mosquitoes as possible. Using a stereo-microscope or a hand lens study the mosquitoes you have collected. Make diagrams showing the different features which might help you to distinguish one kind of mosquito from another.

2. Some schools have slide collections which show the malaria parasite at different times in its life cycle. Study these slides, if they are available, and make diagrams of them.

1.9 At War With the Mosquito: Man's First Efforts

Long before anyone suspected that the mosquito might carry disease, mankind began chemical warfare against this pest. Over 100 years ago, coal oil was poured on pond water in which larval mosquitoes were found. Later, in 1890, kerosene replaced coal oil. In 1905, the then famous Panama Canal Larvicide was developed. This larvicide consisted of 150 gallons of carbolic wood resin, 30 pounds of sodium hydroxide, and 6 gallons of water. When diluted six-fold and sprayed on the surface of swamps, this mixture killed almost all of the mosquito larvae present. Nine years later, when the canal was completed, the area was almost free of mosquitoes. Originally, it was thought that these oily materials killed the wriggling mosquito larvae by suffocating them. This belief appeared to have sound basis: Not only did these oily materials spread out over the water's surface in thin films, but mosquito larvae were known to breathe by projecting breathing tubes, or respiratory discs, into the air. However, in 1918, research proved conclusively that mosquito larvae are poisoned--rather than being suffocated--by layers of crude oil or kerosene. Three years later, mankind took advantage of this knowledge when Paris green--a compound containing copper and arsenic--was used to poison mosquito larva. Within less than ten years, almost all mosquito control was based on the use of this poison. In Brazil's devastating 1938 malaria epidemic, 260 tons of Paris green were poured into larvae-infested streams and swamps.

1.9 Things to Do

1. During 1917 and 1918, research was conducted to find out whether the application of such materials as the Panama Canal Larvicide suffocated--or poisoned--mosquito larvae. Why was this research important? Why does it make any difference how the mosquitoes die, so long as they are killed?

2. Can mosquito larvae live in home swimming pools which are chlorinated? Place mosquito larvae in a five gallon aquarium and determine the maximum concentration of chlorine in which they can survive.

1.10 Killing Adult Mosquitoes

Killing adult mosquitoes proved to be a more difficult task. There are only two ways in which insecticides can be developed. In the first, the chemist makes compounds whose structure he believes will prove toxic to insects. These compounds are then tested for their killing power, and either discarded or put into use depending on the outcome of the tests. In the second method of developing insecticides, the chemist starts with a plant extract or other material which is already known to be toxic to insects; he then attempts to determine its molecular structure so that it can be duplicated and then manufactured on a large scale. An example of this type of development is that of pyrethrum.

Sometime during the 1800s, people noticed that when the dried flowers of Chrysanthemum cineriaefolium--a relative of the common marigold--were burnt, the fumes were toxic to insects. When dried and crushed to a powder, these flowers became known as "pyrethrum." Soon, pyrethrum became a common household insecticide; when dissolved in kerosene, it became the ammunition used in millions of "flit guns." In the early 1900s, when the importance of being able to kill mosquitoes became more apparent, chemists tried to determine the molecular structure of the active ingredient in pyrethrum. However, this task proved to be quite difficult, and it was not accomplished until 1924. In the meantime, the demand for pyrethrum exceeded several million pounds a year. Entire plantations in Kenya, Africa, were devoted entirely to raising the tiny flower. Until the 1950s, these plantations supplied most of the pyrethrum used by the world.

In 1924, two Swiss chemists announced that they had isolated and determined the active ingredients in pyrethrum. As it turned out, there were four active ingredients present. Chemists set out to try to duplicate the structure of the simplest of these four compounds. To put this compound together from readily available raw materials required over a dozen separate steps. By 1951, these problems had been solved, and 10,000 pounds of synthetic pyrethrum--now called "allethrin"--were used in aerosol insect bombs. Later, we shall illustrate some of these procedures, and the problems which accompany them.

1.10 Things to Do

1. Make a "light trap" to catch adult mosquitoes. Place a light in back of some cheese cloth; then wait until enough insects have landed on the cheese cloth to make their capture worthwhile.

2. Pyrethrum and allethrin are often used on camping trips. From a sporting goods store, purchase small quantities of pyrethrum and allethrin and try to determine which is the better killer of adult mosquitoes.

1.11 The Development of DDT

As you may recall, in 1942 the U. S. was at war with Japan. Overnight, malaria became the U. S. Army's number one health problem. In many sectors, malaria produced more casualties than did Japanese gunfire. To add to the problem, the supply of quinine (which had long been used to control the malaria parasite) had been shut off by the Japanese. The final blow came when the 1943 African pyrethrum crop failed.

Years earlier, in 1874, Othmar Ziedler had synthesized dichloro-diphenyl-trichloroethane, or DDT, from chlorine, alcohol, and sulfuric acid. About sixty years later, a Swiss chemist, Paul Muller, was working on the problem of mothproofing clothes. Muller turned his attention to DDT, and began testing the compound. Tests involving DDT and house flies revealed that DDT had a residual action: When sprayed on walls, the DDT film remained lethal to flies for months. Soon thereafter, DDT was used to check the Colorado potato beetle which was threatening Swiss crops. Later, in 1941, when thousands of French refugees fled across the Swiss border to escape the oncoming Germans, DDT was used to delouse these refugees. Encouraged by their success with DDT, the Swiss sold it to the Germans who immediately put it to use on the Russian front. Alerted to the German purchases of DDT, the U. S.

field-tested DDT in Florida. The field tests indicated that DDT might be the most effective insecticide ever discovered. Soon thereafter, DDT was used to control typhus and malaria in Italy.

Next, DDT was brought to bear against malaria in the South Pacific theater. Using army combat planes which had been equipped for spraying DDT, large areas were covered with a fine mist of DDT. Once the inside of buildings had been sprayed with DDT, a thin film of the insecticide remained on the walls, waiting to kill mosquitoes which might alight months after the spray had been applied. With the help of DDT, malaria diminished rapidly as the mosquitoes which carried the disease were killed.

After the war, DDT was applied to the walls of homes and shops all over the world. In 1950, 800,000 rural homes in the Southeastern part of the U. S. were sprayed with DDT. By 1951, this area, like the rest of the U. S., was free of malaria.

As you may recall, in 1948, and then again in 1955, the World Health Organization proclaimed malaria to be the world's number one health problem. At its peak, one person out of every six on earth had malaria. One-half of all the deaths on earth were due to malaria. On the average, someone on earth died of malaria once every ten seconds, night and day.

Using DDT as the principal chemical weapon, the World Health Organization and the governments of the malaria-stricken countries mounted a vigorous campaign against the Anopheles mosquito. In less than twenty years, the death toll claimed by malaria was diminished by two-thirds. By 1966, malaria was no longer the number one killer of mankind.

1.11 Things to Do

1. The text says that ". . . someone on earth died of malaria once every ten seconds, night and day." Yearly, how many people would this amount to?

2. See if you can find out what disease is the present number one killer of mankind.

1.12 DDT Runs Into Trouble

At first, after Paris green and the larvicides had been discovered, many people talked about completely eradicating malaria. Twenty-five years later, though, no one who had been active in the battle against malaria spoke of the possibility of completely eradicating malaria: The mosquito and the malaria parasite had simply proven to be too tenacious a combination. Following the discovery of DDT, however, talk of completely eliminating malaria again sprang up; it looked as though DDT might be able to tip the battle against malaria in favor of mankind.

As you know, when DDT first came into use, it scored one impressive victory after another over the mosquito. The Anopheles mosquito, which carried malaria, was killed off or driven from many of its old haunts. Next, DDT was applied to farmer's fields with the hope that it would kill the insects which often eat from one-fourth to one-third of the growing crop. Again, DDT proved to be the most effective insecticide man had ever produced.

Then, in the early 1950s, disturbing stories about DDT began to circulate. Some of the occurrences reported suggested that DDT was not really very selective: It not only killed insects, but it killed birds, fish, and many mammals as well.

In the late summer and fall of each year, salmon leave the Atlantic Ocean and swim up New Brunswick's Miramichi River to lay their eggs. Each spring, the eggs hatch, giving rise to tiny, young salmon. Several years later, these young salmon leave the river, enter the ocean, and grow to their full size. Years afterward, drawn by some mysterious, little understood instinct, these same salmon return to their place of birth to lay eggs. In 1954, however, the Canadian Fisheries Research Board reported that none of the freshly-hatched salmon had survived the summer. Early in the summer, in an attempt to stop balsam forest damage by the spruce budworm, the area had been sprayed with one-half pound of DDT per acre. The DDT had killed the budworm, but in addition, it had drifted into the Miramichi River, where it had killed all of the young salmon. Brook trout, the insects of the stream, and many species of birds suffered a similar fate.

From Clear Lake, California, came a similar report: In an attempt to kill gnats with DDT, a large number of birds, mainly fish-eating western grebes, had died. Even though DDT had been applied at a maximum concentration which had not exceeded one-fiftieth parts per million, these birds had over 1,500 parts per million of DDT in their bodies. Subsequent research explained what had happened. Minute plankton had absorbed DDT from the water, concentrating it in their tissues. Next, small fish had fed on the plankton, accumulating increasing quantities of DDT with each meal. Then, larger predatory fish had eaten the plankton-eating fish, further concentrating DDT in their tissues. This food chain ended with the western grebe, which ate the larger predatory fish. At each stage of the food chain, the concentration of DDT had increased spectacularly as the DDT in many smaller organisms came to rest within--rather than being excreted by--the larger predators.

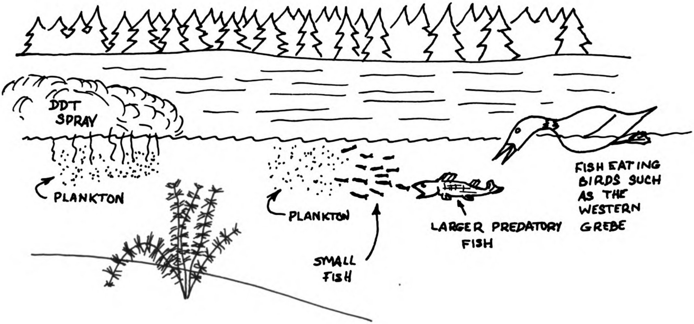


Figure 5. The chain of events which led to the death of hundreds of fish-eating western grebes. At the left, DDT enters the food chain when it is absorbed by microscopic plankton. Center: small fish eat the plankton, concentrating DDT in their tissues. These small fish are then eaten by larger fish. Right: the food chain is completed when the western grebe eats the larger fish, thus further concentrating the DDT.

The discovery that the average person had between 5.3 and 7.4 parts per million of DDT stored in their tissues caused many people to wonder if perhaps the time would come when they, too, would build up lethal concentrations of this poison in their tissues.

In November of 1969, the U. S. Federal Government decided to gradually phase out many of the uses of DDT. The government began this program by outlawing four uses of DDT which accounted for 35% of all of the DDT used yearly. This, in turn, set off a series of legal maneuvers: The U. S. Court of Appeals for the District of Columbia ordered the Secretary

of Agriculture to stop all interstate shipments of DDT within thirty days. In a second legal move, the same court ordered the U. S. Secretary of Health, Education and Welfare to make public the maximum acceptable levels for DDT in foods. The only alternative to either of these courses of action was for the manufacturers of DDT to prove that specific levels of DDT in food were safe. Since earlier tests with DDT had caused cancer in laboratory animals, this alternative seemed unlikely; and, it appeared that DDT might be off the market in the U. S. Meanwhile, the U. S. Department of Agriculture was placed in the uncomfortable position of having recommended the use of DDT for farmers only weeks before it was ordered to ban interstate shipments of the insecticide.

1.12 Things to Do

1. Are some of the insecticides which are currently in use poisonous to fish? To answer this question, over a long time period, add increasingly larger concentrations of current insecticides to a fish tank containing several small fish.

2. What other chemicals have upset our environment? Consult Rachel Carson's prizewinning book, Silent Spring, to answer this question.

3. In what other ways has man damaged his environment? Many recent books have been written on this theme, but Fairfield Osborn's Our Plundered Planet, which was written in 1948, still remains a classic in the field. Thousands of people have enjoyed this book.

4. How poisonous are such substances as garden fertilizer and laundry detergent? Set up a number of one gallon bottles as aquaria by adding elodea and guppies to pond water. After a week or so, begin adding small quantities of fertilizer or detergent. Do these substances damage the balance which exists between plants and fish?

1.13 How Insects Have Developed Resistance to DDT

At about the same time that the problems described were taking place, another ominous problem was also developing. In place after place, one insect after another was becoming harder to kill with DDT. Somehow or other, insects were developing an increasing resistance to poisoning by DDT. As resistance to DDT became the most important single problem faced by insect-control programs, it began to look like DDT's initial victory over the mosquito might prove to be very temporary, indeed.

Gradually, scientists pieced together the puzzle of how insects could develop resistance to DDT. DDT is more irritating than other residual insecticides. As a result, mosquitoes which alight on a wall which has been sprayed with DDT may leave the wall before they acquire a lethal dose. The irritated mosquitoes are not only more active, but they usually head for light, a habit which causes them to leave the house--and its deadly DDT-covered walls.

Certain mosquitoes--perhaps only a small fraction of all mosquitoes--possess an enzyme which enables them to chemically change DDT to another, less toxic form. If, by chance, these mosquitoes receive less than a massive dose of DDT, the enzyme will alter the DDT, enabling the mosquitoes to survive. When the surviving DDT resistant mosquitoes mate with one another, many of their offspring also possess the DDT-changing enzyme. As an increasing percentage of mosquitoes become resistant to DDT, the problem intensifies, and most mosquito-control programs begin to apply DDT in greater concentrations. However, having been previously exposed to DDT, the mosquitoes have an increased capacity to manufacture the DDT-changing enzyme, and so many of them survive this treatment, too.

Laboratory studies with flies showed that if these insects were gradually exposed to increasingly larger concentrations of DDT over a period of several generations, it was possible to raise a generation of "super" flies which were practically immune to almost any reasonable concentration of DDT. Faced with these facts, plus the knowledge that DDT could build up in the tissues of higher organisms, many persons began urging that, henceforth, DDT be used only to fight a holding action until better, safer insecticides could be developed.

At the same time that the shortcomings of DDT were becoming apparent, other mosquito-spread epidemics underscored the urgent need for better insecticides. For example, in 1959, there were over one million cases of tropical onyongnyong fever, a virus disease spread by the Anopheles mosquito. In 1960-1962, Ethiopia suffered the worst yellow fever epidemic of all time. There were 200,000 cases and 30,000 deaths due to this mosquito-spread disease. This outbreak was hundreds of miles closer to Asia than ever before. Asia has never had a yellow fever epidemic, and it would be a woefully fertile field for such an epidemic should one ever get started.

In 1954, a new form of mosquito-spread dengue fever made its appearance. Ordinarily, dengue fever is quite painful, having earned the nickname "break-bone fever"; but, in the past it had seldom produced many deaths. Now the new form of this disease caused hemorrhages and was frequently fatal to children.

In the early 1960s, filariasis, which is caused by a microscopic worm which is spread by certain flies and mosquitoes, surpassed malaria, causing 200 million cases. In 1952, another mosquito-spread disease, Chikungunya virus, was detected in Tanzania, Africa. Six years later, in 1958, it produced the first Asian epidemic ever observed. Five years later, in 1963, in Calcutta, it produced over 400,000 cases.

Spurred by the sudden spread of these new diseases, or by the alteration of the symptoms of older diseases such as dengue, scientists began, as never before, to study the genetics of the mosquito. Hopefully, this study would yield information which would help to control these dangerous pests. Additionally, it was hoped that the study of mosquito genetics would answer the question of whether or not insecticides like DDT had somehow or other accidentally produced these new diseases by altering the genetics of the viruses involved. So diligently did scientists throw themselves into this important endeavor that while only 75 written pages had been required to tell all that was known about mosquito genetics in 1953, by 1967, only thirteen years later, over 800 pages were required to cover the same topic.

As the 1960s ended, it was obvious to all concerned that in order to stop the suffering caused by malaria and other mosquito-spread diseases, the development of new, safer, more effective insecticides was a must.

1.13 Things to Do

1. See if you can develop "super-flies" which can withstand large doses of any of the common insecticides.

2. Make some recommendations regarding the wise use of all insecticides.

1.14 Fighting the Malaria Parasite

Down through the centuries, the malaria parasite has probably killed more people than plague, cholera, typhoid fever, smallpox, or tuberculosis. Furthermore, for each person who died from malaria, perhaps 100 people were weakened and at least temporarily disabled by it. It kept Africa "the white man's grave," and caused Rome to be referred to as "the pestilential city." Yet, when a cure for malaria was finally discovered, it was bitterly rejected by the physicians of the time.

High on the rain-soaked mountain slopes of Peru and Bolivia grows the cinchona tree. At some unrecorded point in the dim past, the Indians living in the area discovered that the cinnamon-colored bark of this tree could be used to cure malaria. The bark was crushed to a powder, added to water, and taken as a medicine by those having malaria. By 1633, news of this cure had made its way into the Spanish missions in Peru. However, when this information was subsequently relayed to Spain, it received a hostile reception from the medical profession.

Centuries earlier, the Greek Father of Medicine, Hippocrates, had listed four fluids, or humors, which were present in the human body. These fluids were: blood, phlegm, yellow bile, and black bile. Hippocrates, and the disciples who followed him, falsely believed that all disease came about as the result of an imbalance in the quantities of these four fluids. Later, this bit of ignorance gave rise to the dangerous practice of blood-letting, or bleeding, the sick. For centuries, those suffering from malaria had been further weakened by being bled by their well-meaning, but ignorant doctors.

Even though the medical profession had rejected the thought that the bark of the cinchona tree could be used to cure malaria, within 70 years the bark became the standard, world-wide cure for malaria. As the demand for the bark mounted, the source of supply became less certain. Removal of the bark killed the tree, of course. As more and more trees were stripped of their bark, the Indians who gathered bark were forced to go deeper and deeper into the jungle to satisfy the demand.

Over the years, both the Dutch and the English had established colonies in such malaria-ridden countries as Java and India. With the bark of the cinchona tree to help ward off malaria, Dutch and English administrators and merchants had settled in these countries. By 1850, it became uncomfortably apparent that the supply of Peruvian and Bolivian cinchona bark was not dependable. This stimulated frantic attempts to either buy or smuggle cinchona seedlings or seeds out of Peru or Bolivia. In 1854, the Dutch sent 500 seedlings to Java. Only 75 of these seedlings survived the ocean voyage, and these were planted in mountainous western Java. Although two million trees were ultimately grown from the seeds produced by the original 75 seedlings, the bark on these trees was of such poor quality that the venture was considered to be a collosal failure. A similar English venture in India also failed miserably. The bark of the trees grown by the English was so poor that the powder produced was given away at post offices throughout India.

In 1865, an English bark trader living in Peru received as a gift from his Indian servant 14 pounds of cinchona seeds. Later, as punishment for having allowed the seeds to fall into foreign hands, the servant was thrown into prison, where he died. Meanwhile, the English bark trader attempted to give the seeds to the English government. When the offer was rejected, the bark trader tried to sell the seeds to the Dutch, who paid a miserly 100 francs for them. When planted in Java, a single pound of seeds produced 12,000 seedlings. At maturity, the bark from these seedlings turned out to be three times as potent a malaria cure as had been the bark of earlier trees. Ultimately, a 50 million dollar industry resulted from the single pound of seeds.

By 1940, there were 110 private cinchona plantations in Java, all of which were started with the offspring from the original pound of seeds. Strangely enough, only the Dutch succeeded in establishing cinchona groves. Attempts to grow cinchona trees in California, Jamaica, Indo-China, the Congo and India all failed miserably; and Java remained the only source of cinchona bark. When, in 1941, the Japanese declared war on England and the United States, one of the first countries to be overrun was Java.

Figure 6. Some of the places of significance in the long history of the cinchona tree.

Just before war had been declared, the U. S. had bought 40 tons of the processed bark, but this supply did ot last long. When the supply of processed bark ran out, 5% of the U. S. soldiers fighting in such malaria-infested egions as the Baatan Penninsula in the Philippines had ttacks of malaria. With the only source of cinchona bark hut off for the duration of the war, England and the U. S. urned to the organic chemist for help.

.14 Things to Do

Be prepared to discuss the following questions:

. Mankind has always been quick to reject new ideas. Just as the medical doctors of the 1600s rejected the use of the bark of the cinchona tree as a malaria cure, so scores of new ideas which ultimately have proven valuable were initially rejected. Can you think of any other examples of this sort of rejection?

. What dangers are associated with the following:
(a) Immediate rejection of all new ideas.
(b) Immediate acceptance of all new ideas.

. What should civilization's attitude be toward all ideas?

.15 Developing Substitutes for Cinchona Bark

Natural sources are not always the best, most depen-able sources for all substances. For example, in the case f quinine, removal of the bark kills the tree. Further, atural sources are often subject to Nature's whims: They ust withstand drought and disease as well as man's demands. or this reason, man would much prefer to manufacture uinine--and other valuable substances--in the laboratory, sing readily available raw materials.

As early as 1820, chemists were able to isolate the ctive ingredient in cinchona bark which killed the malaria arasite. These ingredients were promptly named "quinine" nd "cinchonine." However, being able to isolate the active ngredients of the bark proved to be easier than duplicating t in the laboratory. Later, when the structure of the uinine molecule was worked out, it was found to be so com-lex that duplication in the laboratory initially appeared o be impossible.

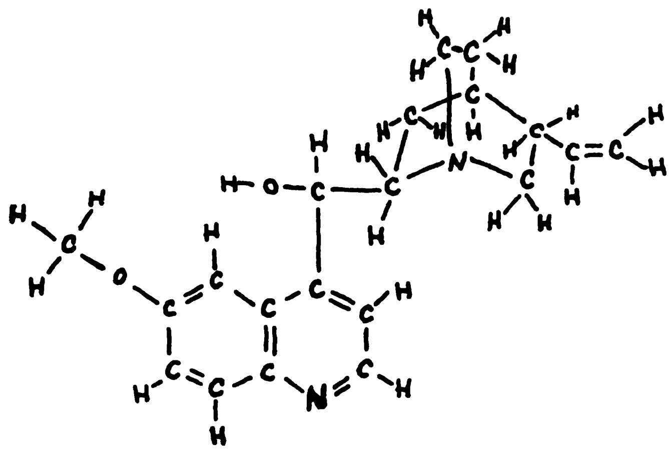


Figure 7. The quinine molecule. Each letter represents one atom of an element. The complexity of this molecule makes it extremely difficult for the chemist to duplicate it in the laboratory.

In the late 1800s, Paul Ehrlich noticed that certain dyes will stain one type of tissue while leaving a second, different type of tissue unstained. To Ehrlich, this indicated that it might be possible to synthesize a drug which would prove toxic to the bacteria which cause disease, but which would not be toxic to the human host. Later, Ehrlich made the observation that the dye, methylene blue, was able to stain the malaria parasite. Using this fact as the starting point, the German chemical industry began an extensive program aimed at producing a compound which could replace quinine. This program resulted in the production of plasmochin in 1926. While plasmochin was an effective killer of the malaria parasite, it turned out to be too toxic for many people. Four years later, in 1930, another anti-malarial drug, atabrine, was put on the market. Like plasmochin, atabrine was also an effective killer of the malaria parasite; but, it also caused a number of undesirable side effects. Only after the Japanese shut off the supply of quinine did atabrine become widely used.

Plasmochin and atabrine were the result of programs which tested over 12,000 compounds. Under the pressure of war-time, in an attempt to produce a better anti-malarial drug, 14,000 more compounds were tested. This crash program resulted in the production of chloroquine, primaquine, daraprim, and paludrine. Finally, in 1944, the U. S.'s Nobel prize-winning chemist, R. B. Woodward, produced synthetic quinine. Unfortunately, the synthesis turned out to be so involved that no synthetic quinine has ever been produced commercially.

One might expect that the synthesis and subsequent testing of over 26,000 compounds might have led to the discovery of an anti-malarial drug. However, each of the anti-malarials ultimately produced had at least one significant defect. Even the original anti-malarial, quinine, was unable to kill one of the several stages of the malaria parasite; and hence, it was unable to completely prevent transmission of the disease. Furthermore, as the unaffected stages of the parasite mature, if the victim no longer is taking quinine, he may suffer a relapse. Atabrine, which was synthesized during the 1930s, but which was not widely used until the quinine supply was shut off during the Second World War, suffered the same defect as quinine, as well as causing a number of objectionable side effects. Chloroquine, which came out of the crash program which had been launched during the Second World War, also simply suppressed the symptoms rather than completely curing malaria. It reduced the victim's fever within 24 hours, and began to kill the malaria parasites within about twice this time. However, chloroquine had to be taken continuously for one to be protected from the disease.

Primaquine had an advantage over quinine, atabrine, and chloroquine in that it was a more effective killer of most species of malaria parasites. Unfortunately, primaquine was not an effective killer of one particular species of malaria parasite, Plasmodium falciparum. Since chloroquine was an effective killer of this parasite, the problem was not a serious one. However, in the late 1950s, chloroquine seemed to lose much of its effectiveness against the species of malaria parasite known as Plasmodium falciparum. This problem was doubly serious since this particular parasite inhabited Viet Nam, where first the French, and later the Americans, were engaged in warfare in the parasites' jungle home.

In 1966, the U. S. Armed Forces in Viet Nam added diamodiphenylsulfone to the treatment of its malaria victims. Although this drug had originally been developed to fight leprosy, rather than malaria, it reduced the malaria fatality rate by one-half. Until this time, malaria had accounted for well over one-third of all U. S. deaths in Viet Nam.

As the all-out chemical campaign against malaria entered its second decade, it became apparent that the search for a safe, effective killer of the malaria parasite was far from over. The World Health Organization urged chemists on in their quest for a drug which would kill all of the many stages of the parasite. Those who set their sights higher hoped for the development of a drug which could be taken easily, yet would confer immunity from the disease for long periods of time. While chemists struggled with the problems of synthesizing and testing new compounds as possible anti-malarial drugs, the parasite continued to kill a million people annually.

1.15 Things to Do

1. Make a model of the quinine molecule. Use styrofoam spheres of various colors to represent the different kinds of atoms in the molecule. Connect these spheres to one another using toothpicks.

2. Historians often make lists of the "one-hundred most significant events in world history." Argue that Ehlich's discovery that certain dyes will stain one type of tissue while leaving a second, different type of tissue unstained, should be included in this list.

3. Learn how to use biological stains. This technique is outlined in many biology laboratory manuals. Even common ink can be used to stain certain tissues, should you lack access to other stains.

PART II

READING MATERIALS FOR A HUMANISTICALLY-ORIENTED SCIENCE COURSE

An Overview of This Section

In Part I of this Appendix, curriculum materials were presented which described the effect that malaria has had on civilization. In Part II the way in which science has contributed to mankind's efforts to eradicate malaria will be discussed. By design, much of the material covered in this section quite closely parallels some of the activities pursued by the Introductory Physical Science Course discussed in Chapter I of this thesis.[1] However, while both the Introductory Physical Science Course and the curriculum materials presented as part of this thesis utilize much the same activities, there the similarity ends. The Introductory Physical Science Course makes little attempt to point out how, or where, these activities relate to the mainstream of civilization, while the materials developed as part of this thesis use the same activities to illustrate the way in which science attacked the problem of controlling the parasite causing malaria. The shift in approach described stems from the belief that in order for students to attach proper value to scientific endeavors, science must be presented in terms of its contribution to civilization.

Developing the Chemical Tools Needed to Fight Malaria

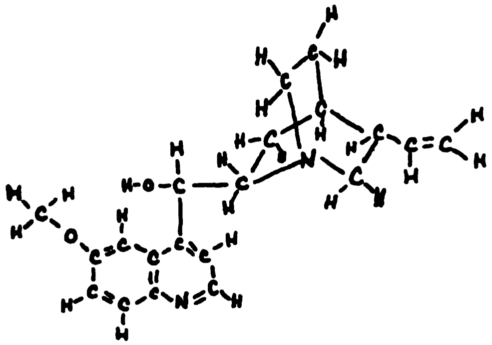
2.0 Developing Drugs to Fight Disease

There are several ways in which chemists usually begin the development of the drugs and insecticides needed to fight malaria. Historically, the first step in this

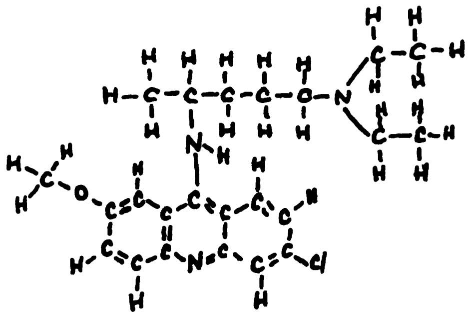
---

[1]Physical Science Study Committee, *op. cit.*

development was taken when the accidental discovery was made that a naturally occurring material, cinchona bark, was toxic to malaria parasites. Naturally, not all of the substances in the bark were toxic, so the chemists' next step was to separate the toxic substance from the inert, non-toxic part of the bark. After this separation was carried out, chemists studied the toxic substance which they had isolated from the bark. Sometimes, this study reveals that the toxic substance has been previously discovered. If this is the case, the molecular structure of the toxic substance will be known, and the chemist may be able to duplicate it. However, in the case of the substance toxic to malaria parasites, research showed it to be a new, previously unknown substance. Because of this, chemists were forced to determine the unknown's molecular structure before they could begin to try to duplicate it.



Quinine



Atabrin

C = carbon atom
H = hydrogen atom
O = oxygen atom
N = nitrogen atom

Figure 8. The molecular structure of some of the compounds which have been used in the fight against malaria. As shown by the key, the letters stand for atoms of the various elements. You can well imagine the scientific "detective work" needed to determine complicated structures such as these.

In the following sections, we shall take a closer look at the processes just described. As you read these sections, remember that procedures such as the ones outlined ultimately enabled mankind to mount a successful campaign against the minute, but deadly, malaria parasite.

2.1 Developing Drugs to Fight Disease: Step (1) Separation of the Substance Which is Toxic to the Malaria Parasite

As you know, over four hundred years ago, the Peruvian Indians discovered that the bark of the cinchona tree could be used to ward off malaria. Later, this discovery reached Europe. However, within a few years, it became apparent that the supply of cinchona bark was not dependable. This realization brought about attempts to establish cinchona plantations in various parts of the world. Unfortunately, most of these attempts were miserable failures. However, these failures caused chemists to make increased efforts to separate the toxic, malaria-parasite-killing part of the bark from the inert, non-toxic part. By 1820, this separation had been completed: The toxic substances extracted from the bark were promptly named "quinine" and "cinchonine." Almost two hundred years had passed between the time that the curative powers of the bark had been recognized and the separation of the active ingredients, quinine and cinchonine! In order to better understand some of the problems which accompany chemical separations, we shall now look at several different separations.

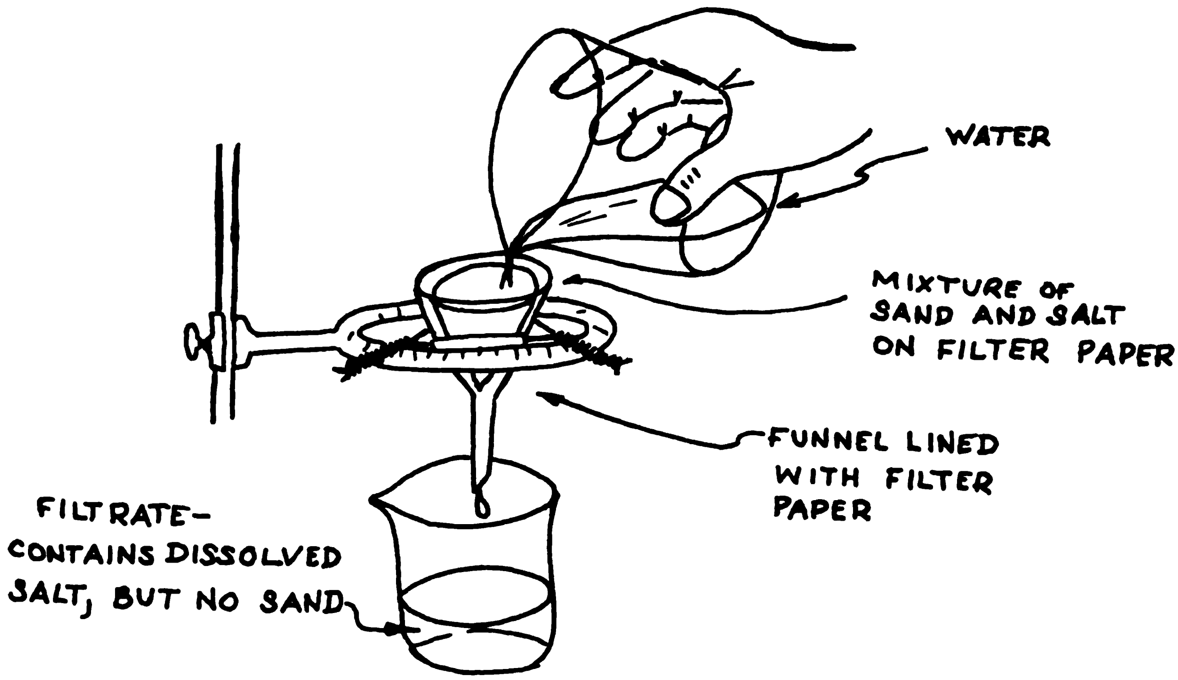


Figure 9. A simple one-step separation. A mixture of sand and salt is placed on the filter paper lining the funnel. Water is poured over the mixture. The salt dissolves in the water, passes through the filter paper, and drains into the beaker beneath the funnel.

Occasionally, separation is a simple matter. For example, suppose you wanted to separate a mixture of common table salt and sand. Past experience with these two substances indicates that water will dissolve salt, but not sand. This indicates that if the mixture of salt and sand is placed on a filter paper through which liquids, but not solids, can pass, and water is poured over the mixture, the salt, but not the sand, will dissolve and pass through the filter. Later, the water which has collected in the beaker may be evaporated and the pure salt recovered.

Unfortunately, few separations are as simple as the one described. Sometimes, each of the solids present in a mixture will dissolve in different solvents. For example, suppose we wished to separate a mixture of salt and iodine. Through experiment, we find that salt will readily dissolve in water, while iodine is not very soluble in water. Further, iodine will dissolve in carbon tetrachloride, but salt will not. This information enables us to plan a separation which utilizes a device known as a "separatory funnel."

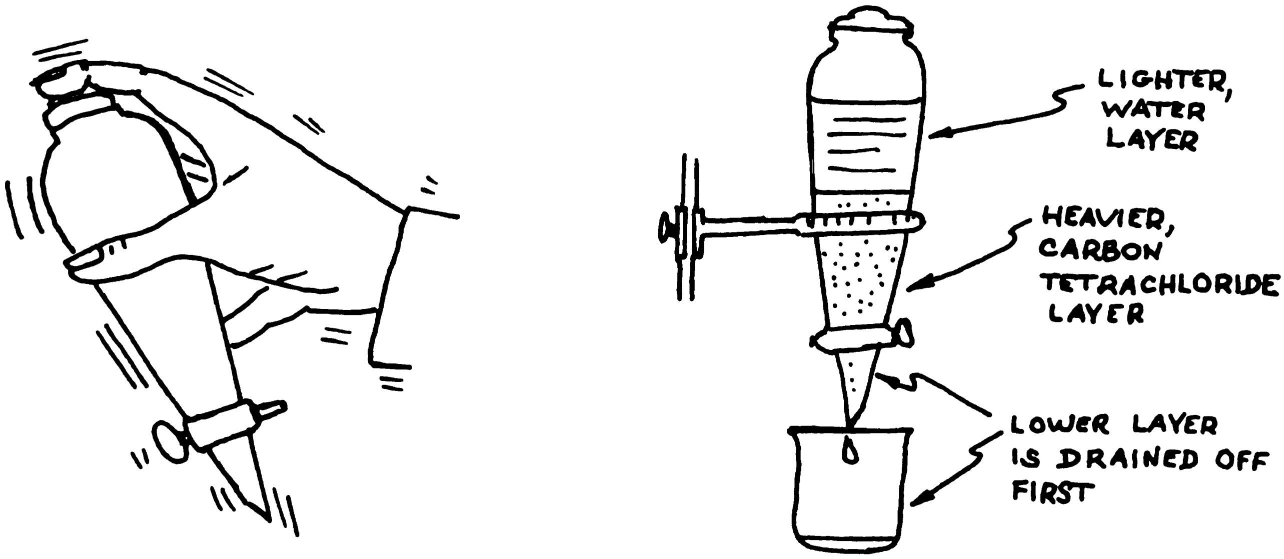


Figure 10. Using a separatory funnel. At the left: The salt-iodine mixture, water and carbon tetrachloride are placed in a separatory funnel and shaken. Right: By carefully draining off the lower, carbon tetrachloride layer, which contains only iodine, the separation may be completed.

First, we place a small quantity of the salt-iodine mixture in the separatory funnel. Next, we add equal volumes of water and carbon tetrachloride. Then, we stopper and shake the separatory funnel until all of the mixture has dissolved.

Since the two liquids have different densities, they form two distinct layers. By opening the stopcock at the bottom of the separatory funnel, it is possible to drain off the lower layer--which contains carbon tetrachloride--without disturbing the upper layer of water. All of the salt is present in dissolved form in the upper, water layer. All of the iodine has dissolved in the lower, carbon tetrachloride, layer.

Sometimes, two solids dissolve in the same liquid, but their solubilities vary greatly with the temperature of the liquid.

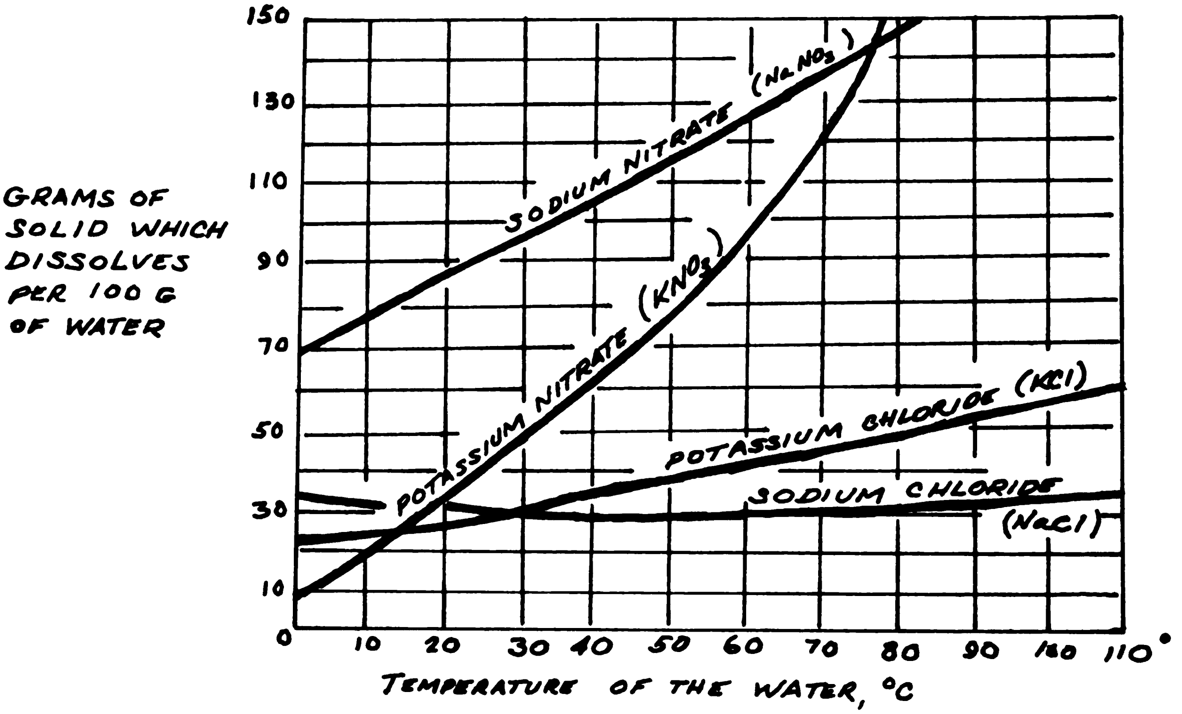


Figure 11. Solubility curves. These solubility curves show how the quantities of certain solids which will dissolve in a given amount of water vary with the temperature of the water. The weight of the solid which will dissolve in 100 grams of water is shown on the vertical axis, and the temperature at which this measurement was made is shown on the horizontal axis.

Suppose we wished to separate a mixture which was about 50% potassium chloride and 50% sodium chloride. We can begin this separation by using a small amount of water at 100°C to dissolve the mixture. Next, we cool the water to 0°C. This causes much of the potassium chloride to crystallize out of the solution, leaving most of the sodium

chloride originally present still in solution. If you study the preceding graph, the reason for this will become obvious: While sodium chloride's solubility is about the same at both 100°C and 0°C, potassium chloride is far more soluble at 100°C than it is at 0°C.

Sometimes, several methods of separation are combined together to separate a complex mixture: Not only is the temperature of the solvent changed, but different liquids are used as solvents as well. For example, suppose we wished to separate a mixture of sodium chloride, lead chloride, mercurous chloride and silver chloride. Laboratory work with these substances reveals that of the four solids, only sodium chloride is soluble in water at room temperature. However, boiling water will dissolve lead chloride, and concentrated ammonium hydroxide will dissolve silver chloride. Mercurous chloride will not dissolve to an appreciable extent in any of these solvents.

Armed with this knowledge, we can devise a scheme for the separation of the four solids: The mixture is placed in a funnel which has been lined with a piece of filter paper. First, water at room temperature is poured over the mixture. This dissolves the sodium chloride, but leaves lead, mercurous and silver chloride on the filter paper. Next, boiling water is poured over the filter paper. This dissolves lead chloride, but leaves mercurous and silver chloride on the filter paper. Lastly, concentrated ammonium hydroxide is poured over the filter paper. This solvent dissolves silver chloride, but merely darkens mercurous chloride. It is worth noting that some liquids react chemically with the solid which they dissolve. For example, silver chloride reacts with concentrated ammonium hydroxide. However, when nitric acid is added to the ammonium hydroxide solution, silver chloride again appears in its original, solid form.

Thus far, we have considered separations which involve solids. Mixtures of liquids are usually separated by a different method which takes advantage of the fact that most liquids boil at different temperatures. Mixtures of liquids are usually separated by a process known as distillation. Distillation is also an extremely important industrial process. Huge quantities of crude oil are distilled yearly; they yield the gasolines, motor oils and a number of assorted substances without which no industrial country could exist.

As we mentioned earlier, distillation depends on the fact that most liquids have different boiling points. When a liquid having a high boiling point is mixed with a liquid having a lower boiling point, and this mixture is gradually heated, most of the liquid having the lower boiling point boils off first, leaving the liquid with the higher boiling point in the original container.

In industrial distillations, the apparatus used takes the form of huge condensing towers, but in the laboratory, the apparatus used in distillation is quite simple. An ordinary test tube equipped with a two-hole stopper through which a bent glass tube and a thermometer have been passed serves as a heating chamber. The bent tubing serves as a delivery tube, conveying the hot vapors from the test tube being heated to a second test tube which rests in a cold water bath. The thermometer shows the temperature of the vapors, and indicates when a new higher boiling component of the mixture begins to boil. Such distillations are known as "fractional distillations" because they result in the separation of the components--or fractions--which make up the mixture.

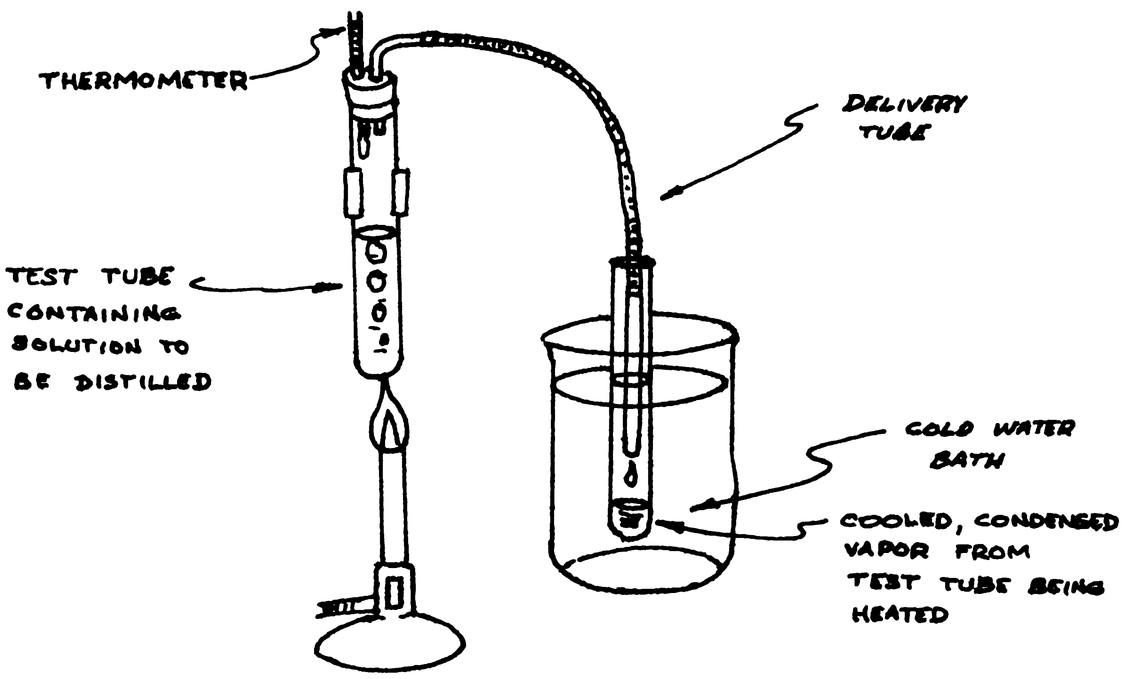


Figure 12. A simple apparatus for the fractional distillation of a mixture of liquids.

For many separations, the apparatus just described would be quite satisfactory. However, even if the liquids making up the mixture have widely separated boiling points, the vapors rising from the heated mixture will contain traces of all of the liquids present. Usually, the liquids having the highest boiling points will be more apt to condense on the sides of the test tube being heated. Then,

they will run back down the sides to the mixture, where they will again be reheated. To insure that this is what actually happens, and thus insure a good separation, researchers often use an apparatus which provides a fractionating column which is more efficient than the sides of a test tube.

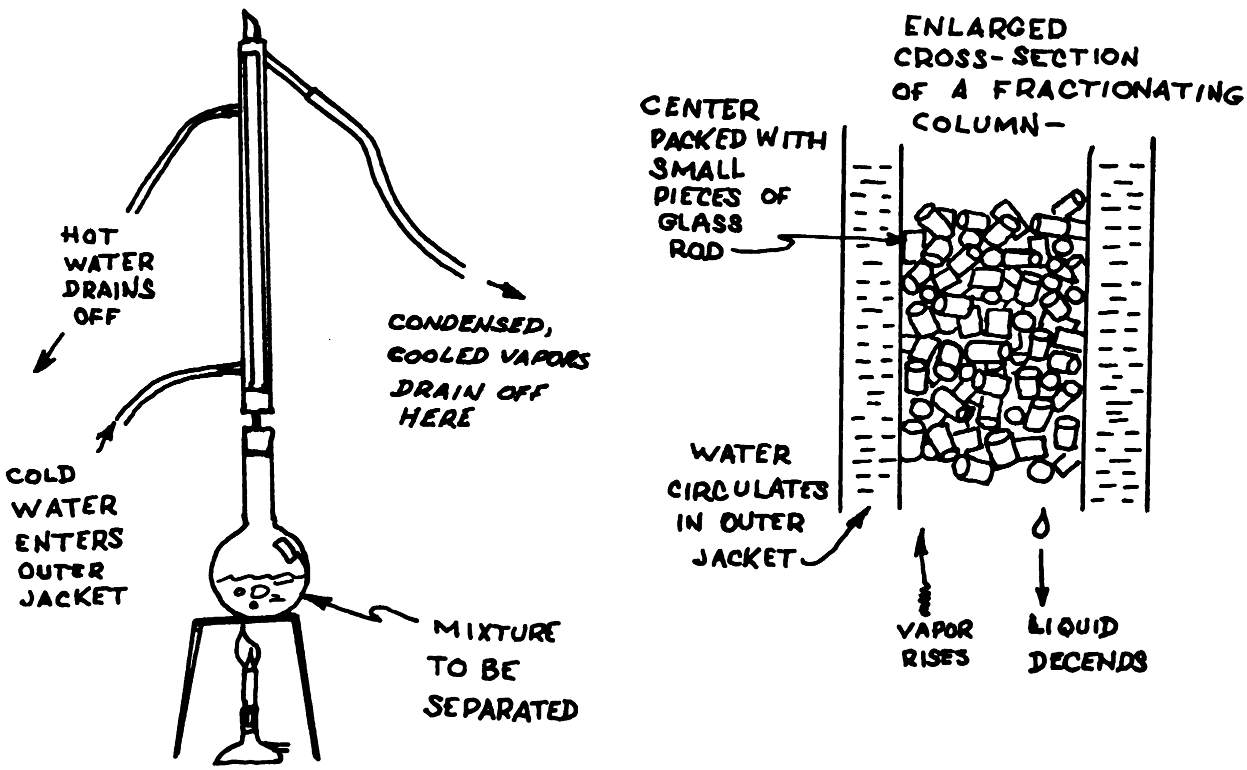


Figure 13. A distillation apparatus which provides a longer fractionating column than a simple test tube. Cold water is circulated in the water jacket which surrounds the fractionating column. The short lengths of glass tubing with which the column is packed serve to help condense the small quantity of the higher boiling liquids which do vaporize.

In our brief, incomplete look at separation procedures, we have seen only two of the more common methods by which mixtures may be separated. You need bear in mind that laboratory separations are extremely important because they are often the first step in the chain of events which may end in the laboratory production of important drugs which may have a far reaching effect on the lives of millions of people.

As you may remember, the purpose of this section was to show some of the ways in which the chemist might go about the task of separating the active ingredient present in a naturally occurring drug, such as cinchona bark, from the inert ingredients which accompany it. After the active ingredients have been separated, the next step is to determine the molecular structure of the active ingredient. This is done by following this procedure:

(1) Determine the physical properties such as the melting point and density of the substance separated.

(2) Find out what elements are present in the compound separated.

(3) Find out how much of each element is present in the compound.

(4) Determine the molecular weight of the compound separated.

(5) Determine the molecular formula of the compound.

(6) Study the chemical properties of the compound.

(7) Systematically break up the compound. (This process is called "degradation"; it allows the chemist to identify the fragments.)

(8) Study the structure of the compound using instruments such as the infra-red spectrometer.

(9) Study the facts revealed by the preceding steps and attempt to arrive at a "most probable molecular structure."

(10) Attempt to determine whether or not the most probable molecular structure previously suggested is actually the correct structure by synthesizing it in the laboratory and comparing the properties of the synthesized compound with the one originally isolated.

In the sections which follow, we shall consider each of these steps in detail.

2.1 Questions and Problems

1. Suppose that a certain kind of clay has been found to have healing powers. How would chemists go about making a healing drug similar to the one in the clay?

2. Why is it often necessary that chemists learn something about the solubility of the individual substances in a mixture before they can separate the components of the mixture?

3. Explain how to separate a mixture of salt, sand and lard. Lard will dissolve in carbon tetrachloride, but neither salt nor sand will dissolve in carbon tetrachloride.

4. Explain how to partially separate a mixture which contains 70 g of sodium nitrate and 70 g of potassium nitrate dissolved in 100 g of water at 70°C. Consult the solubility curves shown in section 2.1 for data concerning the variation in solubility exhibited by these substances at different water temperatures.

5. In question 4, the separation carried out was probably not complete. How much of each substance crystallizes out of solution at 0°C? How much of each substance remains in solution?

6. How would you separate a mixture which contained sodium chloride, lead chloride and silver chloride?

7. Suppose that you were given a liquid mixture which contained pentane (boiling point, 36°C); heptane (boiling point, 98°C); and octane (boiling point, 125°C). How would you go about separating this mixture by fractional distillation?

8. Why is it that after the chemist separates the active ingredient from a naturally occurring drug, that he then begins a thorough, systematic study of it?

2.2 Developing Drugs to Fight Disease: Step (2) Determining the Physical Properties of the Active Ingredients

Once the active ingredients of a naturally occurring drug such as cinchona bark have been separated from the other substances which accompany it, the next step is to determine the physical properties of the active ingredient. If the physical properties of the active ingredient are the same as those of another well-known compound, this may help to identify the active ingredient. If, on the other hand, the physical properties of the active ingredient are unlike those of any known compound, then it must be a new, previously unknown compound. Thus, the process of determining the physical properties of the active ingredient is a necessary step in the production of valuable drugs.

One of the properties which can be used to characterize a substance is its density. Density is weight (or mass) per unit volume. For example, a pound of feathers and a pound of lead both have the same weight, but since the feathers occupy a larger volume, their density is less.

This is easier to understand if we put the definition for density in mathematical terms:

$$\text{density} = \frac{\text{weight of substance}}{\text{volume of substance}}$$

This expression directs us to divide the volume of a sample of the substance into the weight of the sample if we wish to determine its density. For example, suppose we were given a sample of a metallic substance and were asked to find its density. By weighing the sample, we are able to determine that it has a weight of 44.5 grams. The metal is not soluble in water, nor is it porous, so we can measure its volume in this manner: First, we partially fill a graduated cylinder with water. Then, we tip the cylinder on its side and slide the metallic sample into the water. As the metallic sample becomes immersed in the water, the water level in the graduated cylinder rises by an amount equal to the volume of the metallic sample.

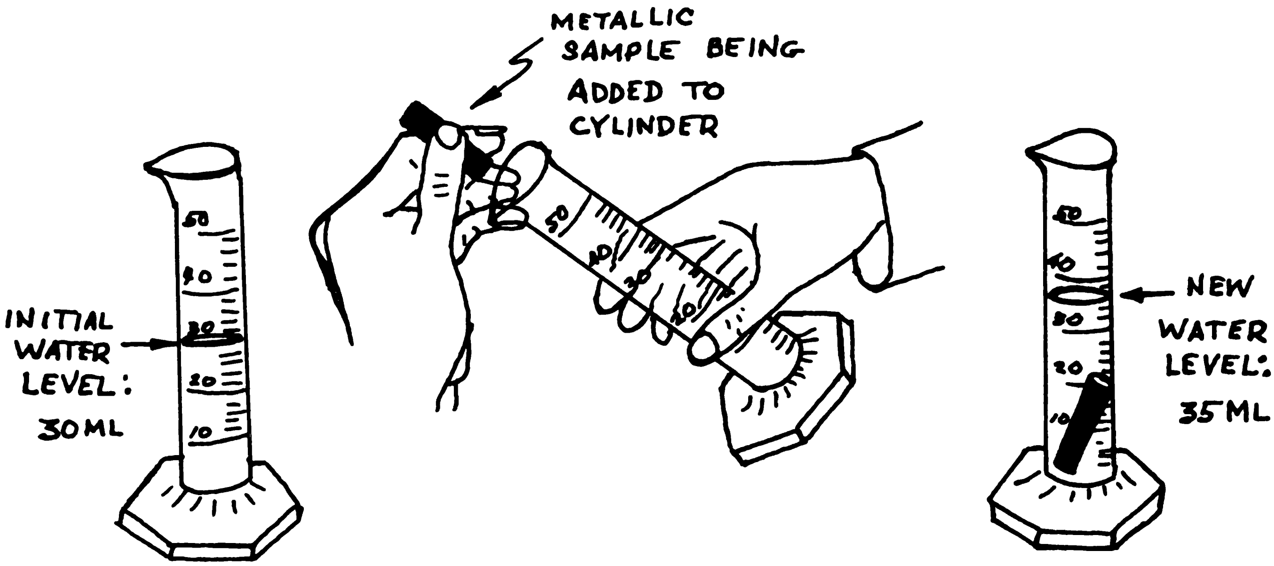


Figure 14. Measuring the volume of a metallic sample. On the left: 30 milliliters of water have been added to the graduated cylinder. Center: The sample is carefully added to the graduated cylinder. Right: The new volume of the water, 35 milliliters, indicates that the volume of the metallic sample is 5 milliliters.

Suppose that our 44.5 gram sample has a volume of 5.0 milliliters. By substituting this data into the expression, density = weight/volume, we can compute the density of the sample:

$$\text{density} = \frac{\text{weight}}{\text{volume}}$$

$$\text{density} = \frac{44.5 \text{ grams}}{5.0 \text{ ml}}$$

$$\text{density} = 8.9 \text{ g/ml}$$

Since one milliliter (ml) is almost exactly the same size as one cubic centimeter (cm^3), this is the same as a density of 8.9 g/cm^3. To find out which metal this might be, we turn to a table listing densities:

Table 9. The densities of some elements.

Substance	Density, g/cm^3
Osmium	22.5
Gold	19.3
Lead	11.3
Copper	8.9
Aluminum	2.7

This table reveals that our sample has exactly the same density as that of copper. This leads us to conclude that the metallic sample is copper rather than some other metal.

Another property which is even more frequently used to identify a substance is its melting or boiling point. A typical melting point determination may be carried out in this manner: A small glass tube which has one open and one sealed end is packed with the solid whose melting point is to be determined. The remaining open end of the now nearly filled tube is sealed by heating, and the tube is attached to a thermometer. The thermometer and attached melting point tube are placed in a liquid which is warmed slowly until a temperature is reached at which the solid begins to melt. This temperature is the melting point of the solid, of course.

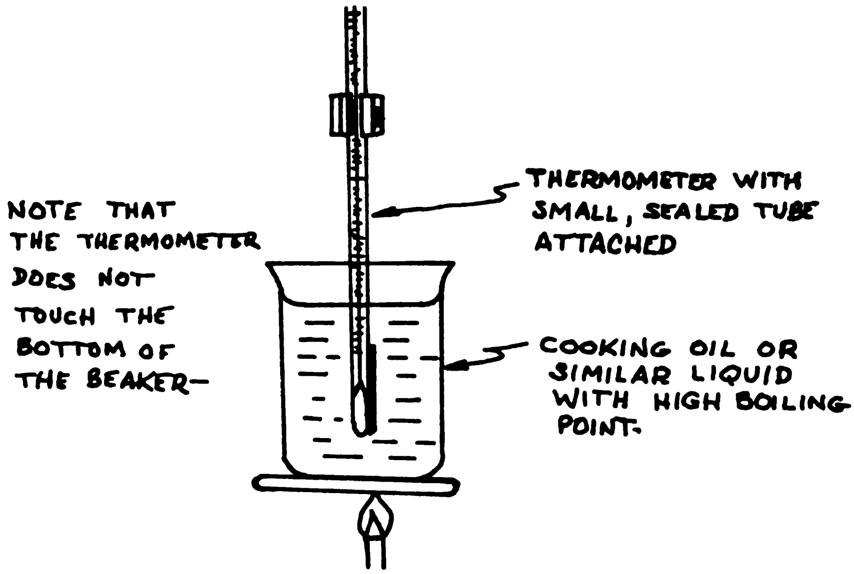


Figure 15. A melting point determination. The small sealed tube contains the solid whose melting point is to be determined. The liquid in the beaker is warmed slowly until the solid in the small tube begins to melt. The temperature at which this occurs is recorded as the melting point of the solid.

Table 10. The densities and melting points of several carboxylic acids. Note that where the densities are so similar as to make identification difficult, the melting points are sufficiently dissimilar so as to make identification easy.

Name of Acid	Density, g/cm^3	Melting Point, ^oC
Formic	1.220	8.4
Acetic	1.049	16.6
Propionic	0.993	-20.8
Butyric	0.958	5.5
Valeric	0.939	-34.5
Caproic	0.936	- 3.9
Enanthic	0.918	- 7.5

There are, of course, many other physical properties which can be used to identify a given substance.

2.2 Questions and Problems

1. What is the density of a metallic sample which has a weight of 60 grams and a volume of 10 cubic centimeters?

2. Gold has a density of 19.3 g/cm^3. Is a ring which weighs 7.0 grams and has a volume of 0.5 cm^3 made of gold?

3. A chemical company has just received a shipment of what is supposed to be valeric acid, density 0.939 g/cm^3. A 10 cm^3 sample of the substance received has a weight of 9.3 g, and a melting point of -3.9°C. Is the substance valeric acid?

4. Once a relationship such as density = weight/volume is known, it may also be used to compute either weight or volume, provided density is known. For example, a certain fuel weighs 50 lbs/ft^3. When a 10,000 ft^3 tank is filled with fuel, what weight of fuel will be present?

2.3 Developing Drugs to Fight Disease: Step (3) Finding Out What Elements Are Present in the Active Ingredient

Suppose that the active ingredient of a naturally occurring drug has been separated from the other substances which accompany it, and that certain physical properties of the active ingredient have been determined. Further, suppose that the properties revealed by this research do not compare with those of any existing, previously known compound. This indicates that the active ingredient is a new, previously undiscovered compound. Under these conditions, the chemist's next step is to determine what elements are present in the active ingredient. Only after this has been done, can he proceed to find out what the compound's molecular structure is actually like.

Since most organic compounds contain carbon and hydrogen, these are often the first compounds which the chemist tests for. This is done by placing a sample of copper oxide, Cu_2O, in a test tube which also contains the active ingredient. When heated, if carbon is present in the active ingredient, it will react with the oxygen in the copper oxide to form carbon dioxide, CO_2:

$$Cu_2O + CX \longrightarrow CO_2\uparrow + 2\,Cu + XO$$

Cu_2O	CX	CO_2	2 Cu	XO
copper oxide	active ingredient	carbon dioxide	copper	remainder of active ingredient in oxide form

Carbon dioxide is a colorless, odorless gas, but its presence may easily be detected by passing the gas formed during the previous reaction into a solution of barium hydroxide, $Ba(OH)_2$. If carbon dioxide is present, it will react with barium hydroxide, forming white, insoluble barium carbonate, $BaCO_3$:

$$CO_2 + Ba(OH)_2 \longrightarrow BaCO_3\downarrow + H_2O$$

carbon dioxide	barium hydroxide	barium carbonate	water

The arrow pointing downward which follows the formula for barium carbonate indicates that this substance is insoluble and settles out of solution. The formation of barium carbonate is taken as proof that the compound contains carbon.

To find out whether or not hydrogen is present in a compound of unknown composition, a similar procedure is used. Copper oxide is again heated in the presence of the unknown. If hydrogen is present in the unknown, it will react with the oxygen in the copper oxide to form gaseous water vapor, H_2O. Usually the water vapor will cool and condense on the cooler parts of the test tube where it can be seen.

To detect the presence of other elements, the unknown is heated in the presence of molten sodium. When this is done, sodium will react with many of the elements present in the unknown, forming a product whose presence is easy to detect. For example, if sulfur is present in the unknown, upon being heated in the presence of molten sodium, it forms sodium sulfide, Na_2S. To test for sodium sulfide, acetic acid, CH_3COOH, is added; this results in the formation of foul-smelling hydrogen sulfide, H_2S:

$$Na_2S + 2\ CH_3COOH \longrightarrow H_2S\uparrow + 2\ CH_3COONa$$

sodium sulfide	acetic acid	hydrogen sulfide	sodium acetate

The formation of hydrogen sulfide may be confirmed by heating the mixture produced by the previous reaction, and passing the vapors over filter paper which has been moistened with lead acetate, $(CH_3COO)_2Pb$. Heating drives off hydrogen sulfide, H_2S, which reacts with the lead acetate, producing a black spot of lead sulfide:

$$H_2S + (CH_3COO)_2Pb \longrightarrow PbS\downarrow + 2\ CH_3COOH$$

hydrogen sulfide	lead acetate	lead sulfide	acetic acid

By using similar chemical tests, the chemist can detect the presence of many other elements.

As you might guess, the chemical analyses which we have described are difficult to perform and very time consuming. Despite these objections, for a long time, this was the only way in which a chemist could analyze an unknown. In more recent years, there has been a marked increase in the development and use of sophisticated instruments for analyzing compounds. Not only are these instruments often faster than chemical analysis, but they usually provide more reliable and more extensive information regarding the molecular structure of the unknown.

One of the most important instruments now used to analyze compounds is the spectroscope. The development of the spectroscope began over three hundred years ago, when Sir Isaac Newton and other scientists found that if sunlight fell on a triangularly shaped piece of glass known as a prism, the sunlight was spread out into the colors of the rainbow.

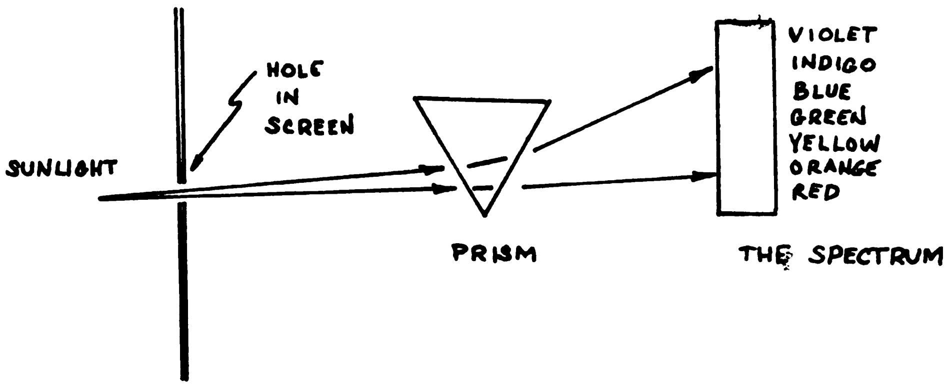


Figure 16. One of the early experiments which led to the development of the spectroscope. When sunlight enters through the small hole at the left and strikes the prism, it is dispersed, or spread out into the colors of the rainbow.

In 1801, William Wollaston, a doctor, became interested in Newton's experiments with prisms. Wollaston added several lenses and a slit to Newton's prism in order to obtain a sharper spectrum. The result was a device which is almost identical to the modern spectroscopes now in use.

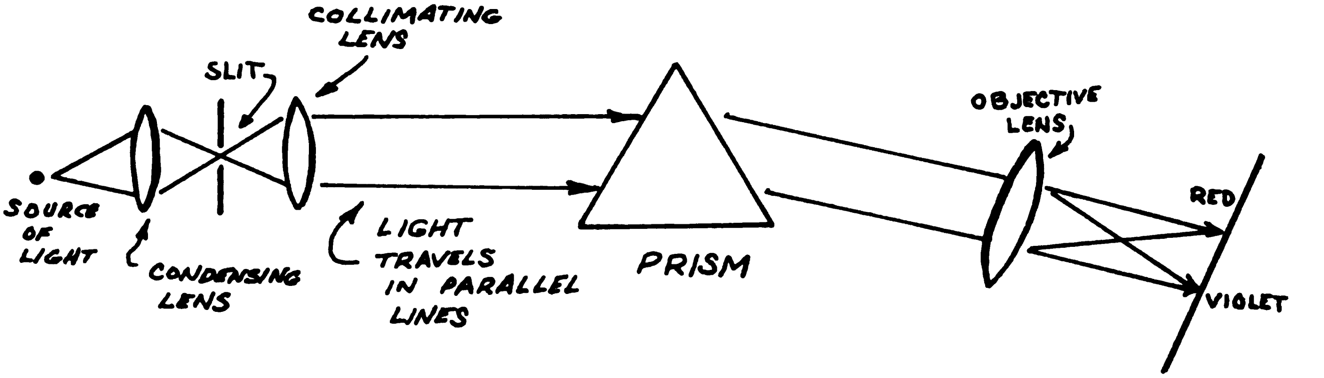


Figure 17. Wollaston's device for studying the spectrum. This arrangement is almost identical to that of the modern spectroscope. The collimating lens simply enables the light passing through the slit to travel in parallel lines.

When Wollaston turned his spectroscope on the sun, he not only saw the rainbow-like spectrum which he expected, but in addition, he saw a large number of dark lines which crossed the spectral array of colors at various places.

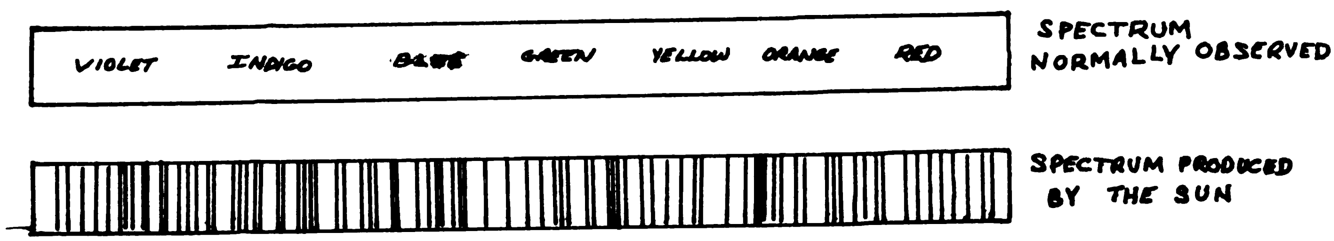


Figure 18. Wollaston's discovery of dark lines in the sun's spectrum.

Unable to explain the presence of these lines, Wollaston gave up his work with light and turned to other experiments.

Thirteen years after Wollaston's moment of frustration, a German optician named Joseph von Fraunhofer counted and charted the lines which Wollaston had seen. Next, Fraunhofer performed a very thought-provoking experiment: He divided the spectroscope's slit into two halves. Then, he passed sunlight through the top part of the slit. Through the lower part of the slit, Fraunhofer passed

light from a bunsen burner in which a sodium compound was being strongly heated. The spectrum produced by the bunsen burner and the heated sodium compound showed yellow lines at exactly the same place that certain dark lines appeared in the sun's spectrum.

For a number of years prior to Fraunhofer's experiment, chemists had known that different elements produced flames of different colors. This fact had long been utilized by people making sky-rockets: For a red rocket, lithium compounds were added to the propellent; for a violet flame, potassium compounds were added. Furthermore, not only did different elements produce differently colored flames, but when the light coming from these flames was passed through a spectroscope, each element had its own characteristic spectrum or pattern of lines. Some elements had yellow or green lines; some had red, blue and green lines; but, no two elements had the same spectrum. The spectrum produced by each element was as distinctive as are the fingerprints of a person.

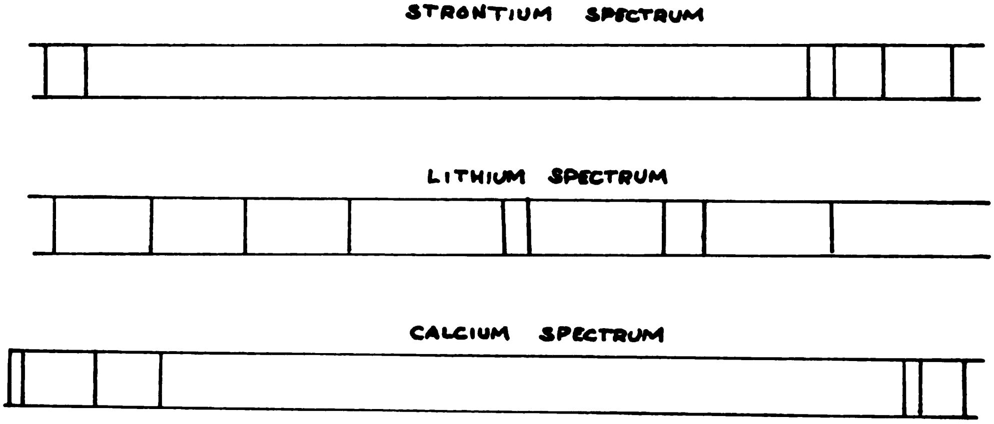


Figure 19. The bright line spectra of strontium, lithium and calcium. The bright line spectrum is produced when the elements shown are heated in a flame and light from this flame is passed through a spectroscope.

Later, other scientists proved that all of the dark lines in the sun's spectrum corresponded exactly with the position of bright lines which were produced by the various elements. For a number of years scientists were unable to explain this phenomena. Then, in 1859, G. A. Kirchhoff, a German physicist, performed an experiment which solved the mystery of the spectral lines. Kirchhoff took a source of white light and focused it on the slit of a spectroscope. This produced the usual rainbow-like array of colors known as a continuous spectrum. Then, Kirchhoff placed a bunsen burner between the source of white light and the spectroscope. Next, he placed a sodium chloride-soaked cloth in the bunsen burner flame. This produced a fluffy yellow flame which chemists knew was due to sodium. When the light coming from this arrangement was passed into a spectroscope, a pair of dark lines appeared superimposed on the rainbow-like array at the exact place in which the bright yellow lines of sodium normally would have appeared.

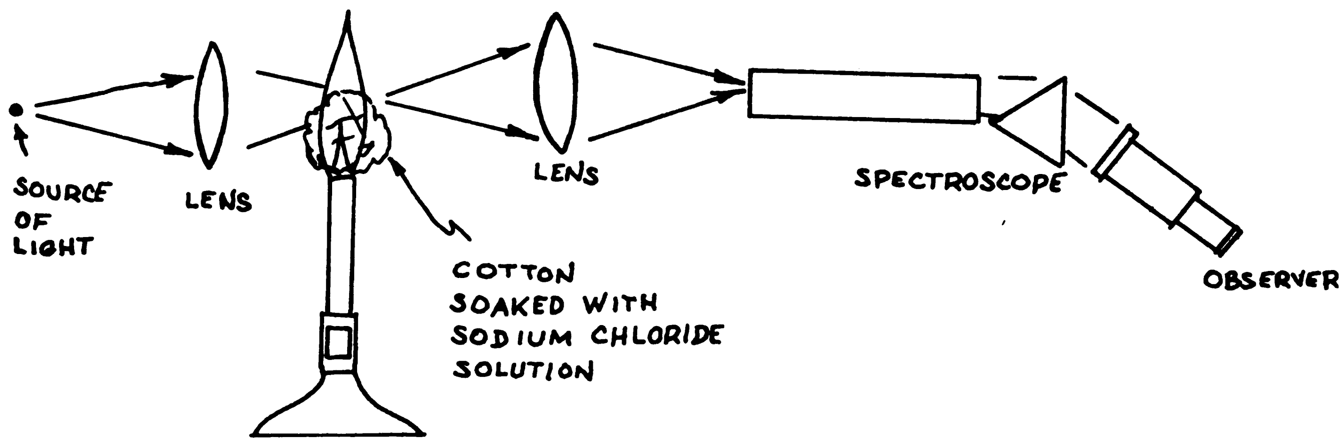


Figure 20. Kirchhoff's apparatus. The source of white light is at the far left. Light from this source passes through the sodium flame and is focused on the spectroscope, which is viewed by the observer on the far right.

Kirchhoff guessed the correct explanation for these observations: The sodium in the flame absorbed the part of the white light which corresponded to the yellow lines usually produced by sodium.

Shortly thereafter, Kirchhoff realized that this discovery opened up a new way for analyzing an unknown of any composition. The first unknown which he sought to analyze was the sun. With the help of his spectroscope, Kirchhoff was able to discover which elements were present in the outer regions of the sun. At the surface, the sun is exceedingly hot, reaching 6000°C. As white light from the surface of the sun passes through the layers of cooler gases which surround it, absorption of light by the elements making up the cooler gases takes place. This absorption of light produces the numerous dark lines first observed by Fraunhofer. Thus, whenever a dark line corresponding to a certain element appeared, this indicated that this element was present in the outer layers of the sun's atmosphere. It was this discovery that helped found the science which we know today as "absorption spectroscopy."

Later, careful study showed that a number of the dark lines in the sun's spectrum could not be traced to any of the known elements. This gave rise to the thought that perhaps certain elements existed on the sun which had not been discovered on earth. In 1868, J. N. Lockyer suggested that one of these spectral lines was due to such an undiscovered element, and he proposed that the missing element be named "helium" after "helios," for the sun. Twenty years later, in 1888, the helium line was produced by mineral samples. Six years afterwards, the element helium was extracted from mineral samples taken from natural gas fields in Canada.

Other discoveries followed rapidly. By 1862, it was known that in addition to the atoms of elements, groups of atoms also produced a characteristic spectrum. Today, chemists often determine the various groups of atoms which are present in a compound by studying its absorption spectrum.

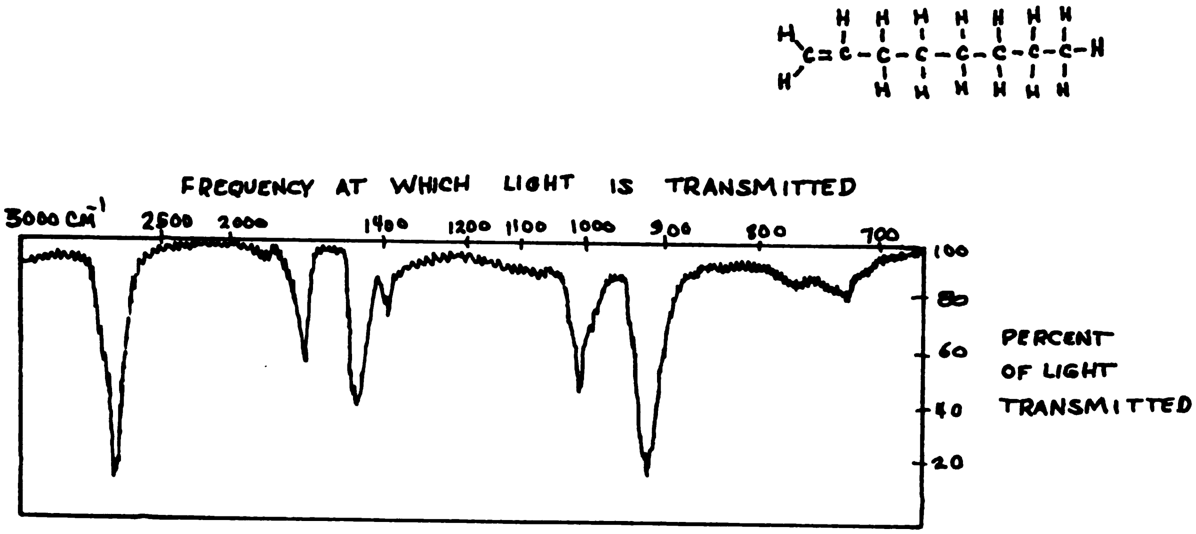
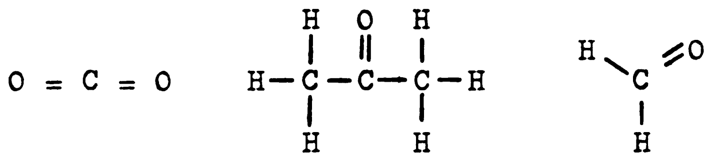


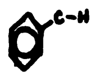
Figure 21. The absorption spectrum of the compound 1-octene. This compound has the structure shown in the inset at the upper right. The numbers shown on the vertical axis indicate the percent of light which is transmitted. The numbers shown on the horizontal axis refer to the wave length of the light absorbed, or the spectral position at which absorption takes place. To a trained spectroscopist, this spectrum is as readable as a newspaper is to you.

Each group of atoms which is present in a compound causes absorption of light to take place at a certain characteristic place on the spectrum. For example, when oxygen and carbon atoms are bonded together in C = O groups, absorption of light takes place at 1690 to 1760 cm^{-1}. Thus, since each of the following molecules contains a C = O group, each would absorb light at 1690-1760 cm^{-1}:



The range, 1690-1760, is given rather than a single specific figure, because the exact point of absorption for a certain group may be shifted somewhat due to the presence of other structural features.

Table 11. The spectral location or frequency at which certain groups of atoms will absorb light, or radiant energy.

Chemical Bond Responsible for the Absorption	Type of Compound or Other Features Present	Absorption Range, cm^{-1}
-C-H carbon-hydrogen	Only carbon-carbon single bonds present.	2850-2960
=C-H carbon-hydrogen	Carbon-carbon double bonds are adjacent.	1350-1470
 carbon-hydrogen	Nearby carbon atoms are bonded together in benzene-like rings.	3020-3080
C=C carbon-carbon	Carbon-carbon double bond.	1640-1680
-C-O carbon-oxygen	Alcohol (-C-OH) ether (-C-O-C-) or acid (-C(=O)-OH) bond.	1080-1300

Little did Wollaston, Newton, Fraunhofer and Kirchhoff realize that their discoveries would some day play an important role in the development of drugs essential to mankind's health.

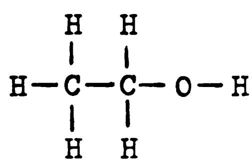
2.3 Questions and Problems

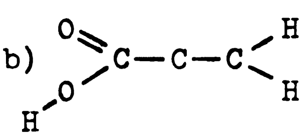
1. Explain how a chemist might prove that an unknown compound contained carbon or hydrogen.

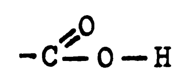
2. What would you expect to see in each of the following instances:
   (a) Sunlight is passed through a prism.
   (b) Sunlight is passed through a series of condensing and collimating lenses, a prism, and then another lens.
   (c) Salt, sodium chloride, is added to a bunsen burner flame and the light coming from the flame is studied with a spectroscope.
   (d) Sunlight is passed through a sodium flame, and then viewed with a spectroscope.

3. Why is it that when viewed with a spectroscope, the sun's spectrum contains a large number of dark lines?

4. A certain compound absorbs light or radiant energy at the following frequencies: 1100 cm^{-1}; 1300 cm^{-1}; and 1670 cm^{-1}. Which one of the following compounds is probably responsible for this spectrum:

(a) 

(b) 

(c) 

2.4 Developing Drugs to Fight Disease: Step (4) Determining the Simplest Formula of the Active Ingredients

Once chemists have learned what kind of elements are present in an unknown compound, they can turn their attention to finding out how many atoms of each element are present. This information can then be used to arrive at what chemists call the "simplest formula" of a compound. In order to fully understand this process, we will need to know certain chemical concepts which we will now explore briefly.

To the layman, the term "formula" usually means a recipe or a set of directions for making something. To the chemist, however, the term means something entirely different. For example, the chemist's formula for common, ordinary water is H_2O. While this set of letters and numbers doesn't tell us how to make water, it does convey several important facts. First of all, the letters shown are known as "symbols." Symbols are used to represent atoms of the various elements. As you know, elements are substances which cannot be further subdivided chemically into other substances. Atoms are the smallest particle into which elements may be divided.

In the formula for water, H_2O, the symbol H stands for hydrogen atoms and the symbol O stands for oxygen atoms. The subscript 2, which follows the H indicates to the chemist that two hydrogen atoms are present for each oxygen atom.

Similarly, the formula for sulfuric acid, H_2SO_4, tells the chemist that two hydrogen atoms, one sulfur atom, and four oxygen atoms are bonded together. Groups of atoms which, like H_2O and H_2SO_4, are bonded together chemically, are known as "molecules." Molecules are the unit particles of many compounds.

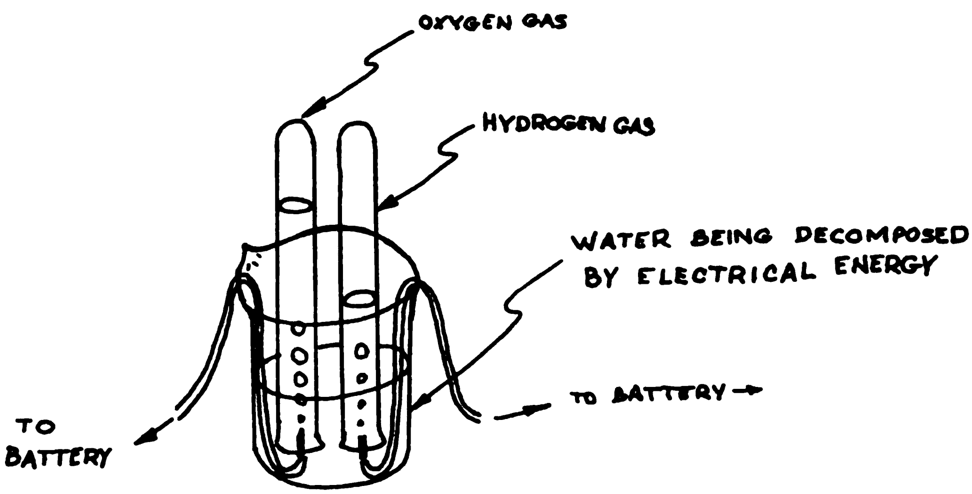


Figure 22. A device for separating the molecular compound water, H_2O, into the gaseous elements hydrogen and oxygen. Electricity supplied by the battery is passed into the water to which a bit of sulfuric acid has been added. As the electricity passes through the solution, it provides the energy needed to break up the water molecules. When the water molecules are broken up, they release hydrogen and oxygen molecules which cannot be further subdivided by the electricity.

By applying ingenious techniques, the early chemists were actually able to compare the weight of individual atoms of the different elements. For example, chemists found that an oxygen atom was sixteen times heavier than a hydrogen atom. Since hydrogen was the lightest element of all, it was originally used as the standard to which all other atoms were compared.

Later, more sophisticated devices were developed which enabled chemists to accurately weigh individual atoms of the different elements. The weight of atoms relative to one another is known as their "atomic weight." For example, oxygen atoms, which are approximately 16 times heavier than hydrogen atoms, have an atomic weight of approximately 16.00, while hydrogen atoms have an atomic weight of 1.00.

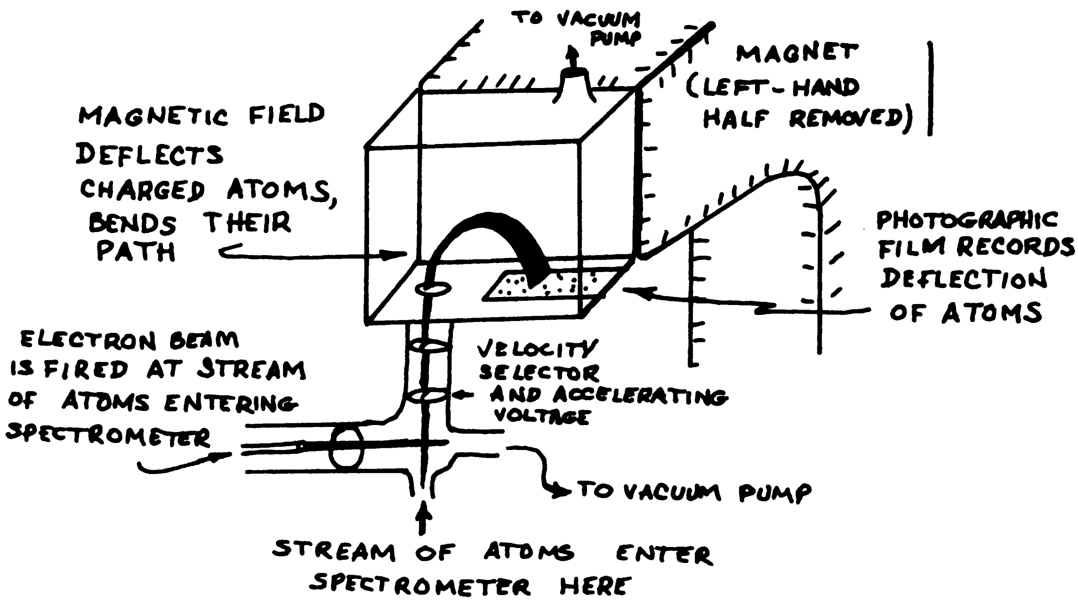


Figure 23. The mass spectrometer, a modern device for weighing individual atoms. At the far left: The atoms whose weight is to be determined acquire an electrical charge. These atoms are then forced into an electrical velocity selector which insures that only atoms having a certain velocity will enter the next chamber. Right: The atoms pass between the poles of a strong magnet which deflects the atoms through a semicircular path. The amount of deflection is greater for lighter atoms and less for heavier atoms, a fact which enables chemists to determine their exact weight.

Having armed ourselves with these concepts, we can now take a closer look at how chemists determine the simplest

formula of the active ingredients in such extremely valuable drugs as quinine. Once chemists have learned what kind of elements are present in an unknown compound, they can turn their attention to finding out how much of each element is present. This process is known as "quantitative analysis." To illustrate the principles of quantitative analysis, suppose we had a 10.00 gram sample of an unknown. Further, suppose that our previous laboratory work had revealed that the unknown was composed entirely of carbon and hydrogen. When heated in the presence of copper oxide, Cu_2O, the carbon and hydrogen in the unknown combine with the oxygen of the copper oxide to form carbon dioxide and water vapor:

$$C_?H_? + Cu_2O \longrightarrow CO_2\uparrow + H_2O$$

unknown	copper oxide	carbon dioxide	water

The question marks following the symbols C and H in the unknown compound simply indicate that we are ignorant of these subscripts. This is what we are trying to find out, of course. The carbon dioxide and water vapor produced in the previous reaction can be passed into separate tubes which contain substances which will absorb these products. By weighing the absorbent-filled tubes before--and after--the unknown compound has reacted with copper oxide, the amount of carbon dioxide and water vapor formed during the reaction may be determined. Knowledge of the percentage of carbon in carbon dioxide allows the chemist to determine the weight of carbon in the unknown compound. Similarly, knowledge of the percentage of hydrogen in water vapor allows the chemist to determine the weight of hydrogen in the unknown.

Suppose that our previous experiment with the 10.00 gram sample of our unknown produced the following data:

weight of carbon in unknown - 7.50 grams
weight of hydrogen in unknown - 2.50 grams

How many carbon and hydrogen atoms are present in these two quantities? We do not know the answer to this question, but we do have enough information to answer it. First of all, we know that the approximate atomic weight of hydrogen is 1.00, and that of carbon is 12.00. If we divide the weight of carbon in the unknown by the atomic weight of carbon, and the weight of hydrogen in the unknown by the atomic weight of hydrogen, we get the relative number of atoms of carbon and hydrogen present:

$$\frac{7.50 \text{ g (weight of carbon in unknown)}}{12.00 \text{ (atomic weight of carbon)}} = 0.625 \text{ carbon atoms}$$

$$\frac{2.50 \text{ g (weight of hydrogen in unknown)}}{1.00 \text{ (atomic weight of hydrogen)}} = 2.50 \text{ hydrogen atoms}$$

What this computation tells us is that there are 0.625 carbon atoms present in the unknown compound for each 2.50 hydrogen atoms. Since chemical formulas utilize whole numbers of atoms, we divide the smaller number (0.625 carbon atoms) into the larger number (2.50 hydrogen atoms) in order to get a simpler ratio:

$$\frac{2.50 \text{ hydrogen atoms}}{0.625 \text{ carbon atoms}} = 4 \text{ hydrogen atoms/carbon atom}$$

The result of this computation indicates that there are four hydrogen atoms present for each carbon atom. This means that the simplest formula for our unknown compound is CH_4.

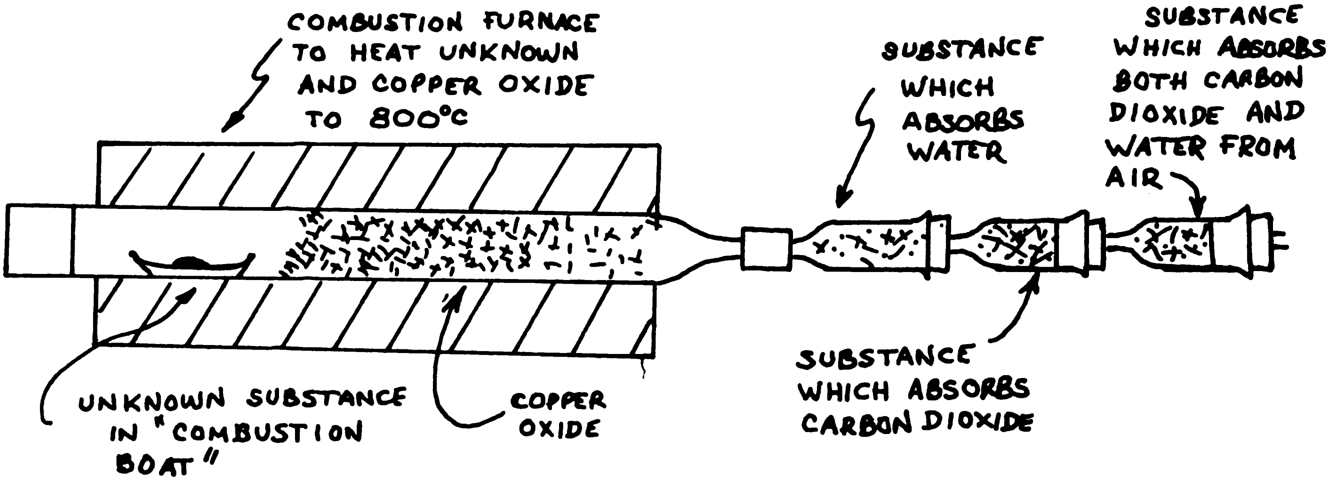


Figure 24. An apparatus which can be used to determine the weight of carbon and hydrogen present in an unknown. At the left: A large tube, which is enclosed by a combustion furnace, contains the unknown plus copper oxide. The two tubes to the right of the combustion furnace contain substances which will react with carbon dioxide and water vapor. As these substances react, both tubes will gain weight, of course. The last tube on the right contains a mixture of absorbents which prevent carbon dioxide and water vapor present in the air from reaching the absorbent-filled tubes which are nearest the sample.

As we shall see later, there is only one way in which one carbon and four hydrogen atoms can be arranged to make a molecule. Usually, there are many ways in which the carbon and hydrogen atoms in a molecule can be arranged. Since the properties of a compound depend not only on the kinds and numbers of atoms which are present, but on the way in which they are arranged as well, further study is needed before the chemist can reproduce the unknown in the laboratory.

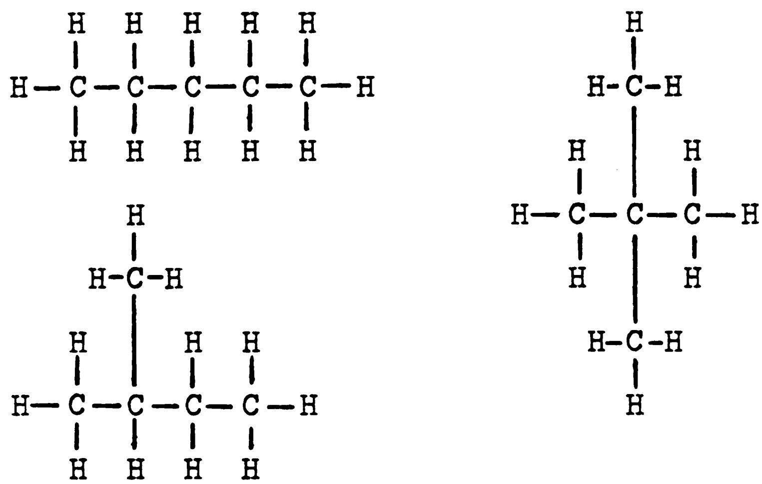


Figure 25. Some of the ways in which five carbon atoms and twelve hydrogen atoms can be arranged. After a chemist has worked out the simplest formula for a compound, he can turn to the problem of determining the actual arrangement of the atoms in the molecule.

Sometimes, the actual formula of the molecule will be some multiple of the simplest formula. Suppose, for example, that the simplest formula of an unknown was CH_3. No such molecule is possible, but a molecule with the formula C_2H_6 is quite possible. Thus, the actual formula simply contains twice as many atoms as does the simplest formula.

Below: A sample problem which summarizes the procedure used to determine the simplest formula of a compound.

Out of the U.S. labor force of 71 million, perhaps 13 million people suffer from arthritis. Cortisone is an extremely valuable compound in the treatment of arthritis. Originally, cortisone was obtained from the pituitary glands of sheep, but it takes 80 million sheep to produce a pound of cortisone. Today, cortisone is produced much more cheaply in the laboratory. To see how the simplest formula for cortisone was worked out, consider the following sample problem:

> A 3.18 gram sample of cortisone is analyzed and found to consist of 2.28 g of carbon; 0.26 g of hydrogen and 0.64 g of oxygen. What is the simplest formula for cortisone indicated by this data?

Solution:

(1) Divide each of the weights given in the analysis by the atomic weight of the element involved.

$$\frac{2.28 \text{ g carbon}}{12.00} = 0.19 \text{ carbon atoms}$$

$$\frac{0.26 \text{ g hydrogen}}{1.00} = 0.26 \text{ hydrogen atoms}$$

$$\frac{0.64 \text{ g oxygen}}{16.00} = 0.04 \text{ oxygen atoms}$$

(2) Divide the relative numbers of carbon, hydrogen and oxygen atoms just obtained (0.19, 0.26, and 0.04) by the smallest of these three figures to further simplify the numbers:

$$\frac{0.19 \text{ carbon atoms}}{0.04} = 4.75 \text{ carbon atoms}$$

$$\frac{0.26 \text{ hydrogen atoms}}{0.04} = 0.65 \text{ hydrogen atoms}$$

$$\frac{0.04 \text{ oxygen atoms}}{0.04} = 1.0 \text{ oxygen atom}$$

(3) This gives us a formula of $C_{4.75}H_{6.5}O$, but since chemists prefer to use formulas having only whole numbers, we must multiply all of the numbers shown in the formula by some number until the formula has only whole numbers. We begin by multiplying all the subscripts by 2:

$$2 \times C_{4.75}H_{6.5}O = C_{9.5}H_{13}O_2$$

The "$C_{9.5}$" part of the formula is not a whole number, so we again multiply the last formula shown by 2:

$$2 \times C_{9.5}H_{13}O_2 = C_{19}H_{26}O_4$$

The last formula shown, $C_{19}H_{26}O_4$, utilizes only whole numbers, and therefore is acceptable as the simplest formula for cortisone.

It is worth noting that the work which we have desdribed in this section is based on the physical law which chemists call "the conservation of matter." This law states that significant quantities of matter are neither created nor destroyed during chemical reactions. To illustrate the law of conservation of matter, suppose that 12.00 grams of carbon reacts with 32.00 grams of oxygen. The product, carbon dioxide, must weigh exactly 44.00 grams (12.00 + 32.00)--it cannot weigh more--or less--than this unless matter has either been created or destroyed during the reaction. This important law is the basis upon which the science of chemistry was originally erected.

2.4 Questions and Problems

1. The chemical formula for sugar is $C_6H_{12}O_6$.
   (a) How many carbon atoms does this formula show?
   (b) How many atoms--of all kinds--are present in a molecule of sugar?

2. Define the following terms:
   (a) element; (b) atom; (c) compound; (d) molecule.

3. Do you think it would be possible to have:
   (a) A molecule of oxygen?
   (b) An atom of water?

4. A chemist says that, "Carbon has an atomic weight of 12.00." What does he mean by this?

5. An unknown compound known to contain only carbon and hydrogen atoms is to be analyzed. How can a chemist find out how many grams of each substance are present in the sample? Draw a diagram of the apparatus used in this determination.

6. Years ago, sailors on long ocean voyages used to suffer terribly from scurvy. Scurvy is caused by a lack of vitamin C. When a sample of vitamin C was isolated and then analyzed, it was found to be 7.20 g carbon, 0.80 g hydrogen and 9.60 g oxygen. What is the simplest formula for vitamin C?

7. One of the most important medicines is penicillin, which was accidently discovered by Alexander Fleming in 1929. An analysis of a sample of penicillin showed it to be 3.20 g sulfur (atomic weight 32); 3.20 g oxygen; 1.40 g nitrogen (atomic weight 14); 0.80 g hydrogen; and 7.20 g carbon. What is the simplest formula for penicillin?

8. What is meant by the phrase "the conservation of matter"?

2.5 Developing Drugs to Fight Disease: Step (6) Determining the Molecular Weight of the Active Ingredients

As we saw in the preceeding section, knowing the simplest formula of a compound doesn't necessarily mean that a chemist has enough information to identify or duplicate the compound. For example, acetic acid, CH_3COOH, formaldehyde, HCHO, and glucose, $C_6H_{12}O_6$, all have exactly the same simplest formula--CH_2O--, yet these compounds are completely unlike one another. Knowledge of the simplest formula, plus the molecular weight of each of these compounds would allow a chemist to quickly identify them, however: The molecular weight of acetic acid is 60; formaldehyde has a molecular weight of 30; and the molecular weight of glucose is 180.

If we know the <u>actual</u> formula of a compound, computing its molecular weight is easy. For example, to compute the molecular weight of water, H_2O, all we need to do is add up the weights of hydrogen and oxygen as shown by the formula. The formula, H_2O, shows that there are two hydrogen atoms present. Each hydrogen atom has a weight of 1.00; so we multiply 1.00 x 2:

$$1.00 \times 2 = 2.00$$

Each oxygen atom has an atomic weight of 16.00, and only one oxygen atom is shown in the formula, so we multiply 16.00 x 1:

$$16.00 \times 1 = 16.00$$

Lastly, we add these two products together:

$$\begin{array}{r} 2.00 \\ +\ 16.00 \\ \hline 18.00 \end{array}$$

The total sum shown above, 18.00, is the molecular weight of water. This indicates that a water molecule is 18.00 times heavier than a hydrogen atom, which has an atomic weight of 1.00. However, in actual situations involving an unknown, knowledge of the molecular weight almost always precedes knowledge of the actual formula. Suppose, as in our previous example, that we know that the simplest formula of an unknown compound is CH_2O. However, three known compounds, acetic acid, molecular weight 60; formaldehyde, molecular weight 30; and glucose, molecular weight 180, all are consistent with the simplest formula of CH_2O. Which one of these compounds is the unknown? The answer to this question will depend on the chemist's determination of the molecular weight of the unknown. If the unknown has a molecular weight of 30, it is most likely formaldehyde; but if the unknown has a molecular weight of 60 or 180, then it must be acetic acid or glucose.

Below: The procedure for computing the molecular weight of a compound from its actual formula. The formula shown is that of glucose, $C_6H_{12}O_6$.

$C_6H_{12}O_6$		Atomic Weight	x	Number of Atoms of the Element	=	Weight of Element Present
Weight of carbon present	=	12.00	x	6	=	72.00
Weight of hydrogen present	=	1.00	x	12	=	12.00
Weight of oxygen present	=	16.00	x	6	=	96.00
Molecular weight of $C_6H_{12}O_6$					=	180.00

There are many ways in which molecular weights may be determined. Some methods are applicable only to compounds which are gases or easily vaporized liquids. Other methods utilize sophisticated pieces of apparatus such as the mass spectrometer or the ultracentrifuge. We shall take a close look at the freezing point depression method of determining molecular weights. This is a simple laboratory procedure which requires a minimum of laboratory apparatus, yet it may be used with a variety of different compounds.

The freezing point depression method for determining molecular weights is based on scientific research done in 1883 by Francois Raoult, a French chemist. Raoult found that solutions always had lower freezing points than did the liquids used to make them. For example, a solution of sugar in water always has a lower freezing point than does pure water. Incidentally, putting salt on an icy street is a common application of this knowledge.

When Raoult continued to probe the phenomena of freezing point lowering, he uncovered several other interesting relationships: When the molecular weight, in grams, of a substance was dissolved in 1000 grams of water, the resulting solution always froze at approximately -1.86°C.

Furthermore, it seemed to make no difference what molecular substance was dissolved in water; the freezing point was always lowered by the same amount.

Table 12. Data which reveals that whenever the molecular weight, in grams, of any molecular substance is dissolved in 1000 grams of water, the freezing point of the solution formed is always approximately -1.86°C. The freezing point of pure water is, of course, 0°C.

Weight of Water Used to Make the Solution	Name and Molecular Weight of the Substance Used to Make the Solution	Weight of the Substance Added to 1000 g of Water	Approximate Freezing Point of the Solution
1000 g	sugar, MW 180	180 g	- 1.86°C
1000 g	urea, MW 60	60 g	- 1.86°C
1000 g	methyl alcohol, MW 32	32 g	- 1.86°C

Raoult knew that the molecular weight, in grams, of any substance must contain the same number of molecules. From this knowledge, and from the data he had collected concerning the freezing point of solutions, Raoult concluded that it was not the kind of molecules present which determined the freezing point lowering of a solution. Instead, said Raoult, what determined the freezing point of a solution was the number of particles actually present.

Not long after Raoult made these discoveries, chemists realized that they now had a reliable way to determine the molecular weight of certain substances. In order to determine the molecular weight of a substance, chemists first prepared a solution which contained carefully weighed amounts of both water and unknown. The freezing point of this carefully prepared solution could then be compared--mathematically--to the freezing point of a hypothetical water solution which contained enough of the unknown to lower the freezing point of 1000 g of water to -1.86°C. The quantity of the unknown required to do this, of course, would be the unknown's molecular weight, in grams.

For example, suppose 10 grams of a substance is dissolved in 100 grams of water, and that the resulting solution has a freezing point of -0.93°C. First, we must compute how much of the unknown would be needed to prepare a solution of comparable concentration which would involve 1000 grams of water. This is done by using a mathematical proportion:

$$\frac{1000 \text{ g water}}{100 \text{ g water}} \times \frac{x \text{ grams of unknown}}{10 \text{ grams of unknown}}$$

$$x = 100 \text{ g of unknown}$$

What we have accomplished with this proportion is to increase the quantity of unknown called for by the ratio, 1000 g water/100 g water. Since 1000 g of water is ten times 100 grams of water, we need 10 times as much unknown as was originally needed, or 100 g.

Now, we know that when 100 grams of the unknown is dissolved in 1000 grams of water, the solution will freeze at -0.93°C. Next, we can compute the weight of unknown which will have to be dissolved in 1000 g of water in order to produce a freezing point of -1.86°C. This quantity will be the molecular weight of the unknown, in grams:

$$\frac{100 \text{ g unknown/1000 g water}}{x \text{ g unknown/1000 g water}} = \frac{-\ 0.93^{\circ}\text{C}}{-\ 1.86^{\circ}\text{C}}$$

$$x = 200 \text{ grams}$$

The molecular weight of the unknown is 200.

While these computations seem very distant from the problem of stopping a disease such as malaria, you must remember that without a reliable way to determine molecular weights, the identity of the active ingredient in a drug such as quinine may remain a mystery: Until mankind learned how to look at scientific phenomena--such as the freezing-point-lowering of solutions--from a mathematical standpoint, his scientific progress was very slow.

Not all unknowns are water soluble, of course. In this event, solubility tests are carried out to determine in which liquids the unknown will dissolve. Then, a solution using measured amounts of one of these liquids and the unknown is prepared. Next, the freezing point of the solution is determined.

It is worth noting that each liquid has its own characteristic freezing point lowering. For example, as you know, when one molecular weight, in grams, of a substance is dissolved in 1000 grams of water, the solution freezes at -1.86°C. However, when one molecular weight, in grams, of any substance is dissolved in 1000 grams of benzene, the solution always freezes at 4.90°C below the normal freezing point of benzene. The fact that most liquids also exhibit a regular freezing point lowering provides chemists with a wide range of solvents which may be used in place of water.

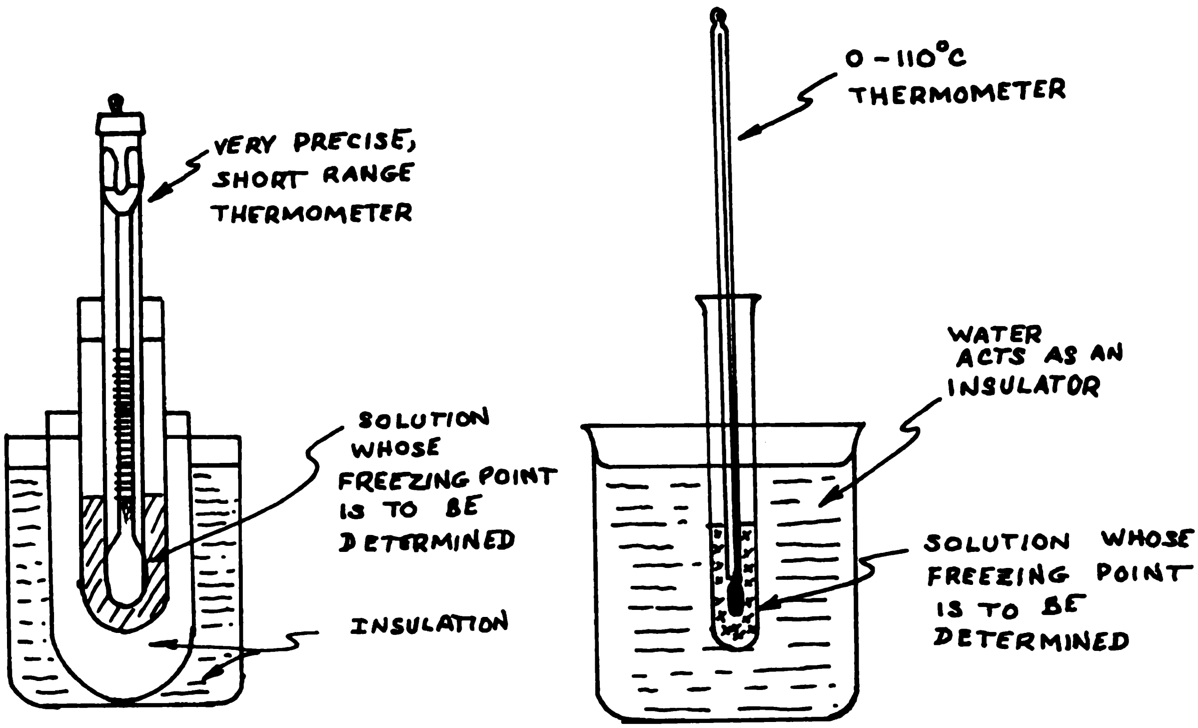


Figure 26. Laboratory apparatus for determining the freezing point of a solution. At left: The chemist's apparatus. The wire loops serve as stirring rods. The multiple containers serve to insulate the solution of interest, which is in the innermost container. With this insulation, cooling takes place very slowly and an accurate freezing point determination is possible. The thermometer is an expensive adjustable-range instrument. Right: A less sophisticated apparatus. This set-up utilizes an ordinary thermometer and has less insulation, allowing a more rapid temperature change. While less accurate, certain determinations may be carried out with this device.

Table 13. Some solvents and the freezing point lowering which they exhibit when one molecular weight, in grams, of any molecular substance is dissolved in 1000 grams of the solvent.

Solvent	Freezing Point of the Pure Solvent	Freezing Point Lowering Produced by Dissolving One Molecular Weight of Any Molecular Substance in 1000 g of Solvent
Acetic acid	17.0°C	3.90°C
Benzene	5.60°C	4.90°C
Camphor	180 °C	40.0 °C

2.5 Questions and Problems

1. An unknown substance appearing in a sample of crude oil has a simplest formula of CH_2. Which one of the following compounds is most apt to be the unknown: butane, C_4H_{10}; butene, C_4H_8; or octene, C_8H_{16}?

2. Suppose we learn that the unknown in question number one has a molecular weight of 56. Which one of the two compounds which fit the simplest formula data previously presented is the unknown?

3. Which one of the following compounds, all of which have the same simplest formula, have a molecular weight of 42: ethene, C_2H_4; propene, C_3H_6; or heptene, C_6H_{12}?

4. One of the characteristics of water is that its solutions display a regularity in their freezing points. What is this regularity?

5. When 100 grams of a certain unknown is dissolved in 1000 grams of water, the solution freezes at 0.93°C. What is the molecular weight of the unknown?

6. 20 grams of an unknown are dissolved in 100 grams of water. The freezing point of this solution is -3.72°C. What is the molecular weight of the unknown?

7. 10 grams of an unknown are dissolved in 100 grams of benzene. The freezing point of the solution is 3.15°C. Pure benzene normally freezes at 5.60°C, and the freezing point lowering which is produced when one molecular weight, in grams, of a substance is dissolved in 1000

grams of benzene is 4.90°C. What is the molecular weight of the unknown?

2.6 Developing Drugs to Fight Disease: Step (7) Studying the Chemical Properties of the Active Ingredients

By 1970, chemists knew the formulas of several million organic compounds. Further, there seemed to be no limit to the number of new compounds which were prepared each year. With all these compounds to choose from, it might seem that the identification of an unknown compound would be extremely difficult, if not impossible. However, the chemist can greatly simplify the problem of identification of an unknown compound by studying its chemical properties.

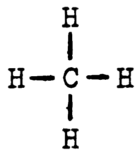
The phrase "chemical properties" refers to the way in which a substance will react chemically with other substances. Once the chemical properties of an unknown have been established by laboratory work, it is usually possible to place the unknown in one of about twenty different chemical families.

All of the members of a given chemical family always contain the same group of atoms which cause the family to have the properties which characterize it. For example, all members of the chemical family known as the alcohols contain an -OH, or hydroxyl group. The presence of this group of atoms bestows certain easily identifiable chemical properties on the molecule. When alcohols react with potassium dichromate, $K_2Cr_2O_7$, in the presence of sulfuric acid, either an aldehyde or a ketone forms. No other family of compounds reacts in exactly this manner.

Instead of containing unique groups of atoms, some chemical families are characterized by the presence of certain kinds of chemical bonds. In the most common kind of chemical bonding, carbon atoms attach themselves to four other atoms. Since each point of attachment is known as a "chemical bond," we say that carbon atoms can form four chemical bonds. Chemists usually show this in the following manner:

```
 |
-C-
 |
```

In this representation, the letter C stands for a single carbon atom. Each line represents a single bond which carbon atoms can form with atoms of other elements. For example, if carbon forms chemical bonds with four hydrogen atoms, this molecule results:



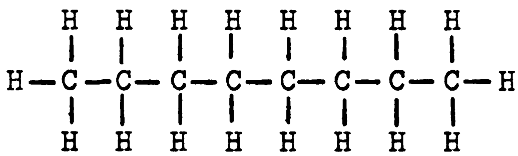
The molecule shown is methane, or natural gas, which is a commonly used fuel.

Most elements have a definite, fixed number of chemical bonds which they may form. For example, hydrogen atoms may form only one chemical bond with other atoms, and oxygen may form two chemical bonds with other atoms.

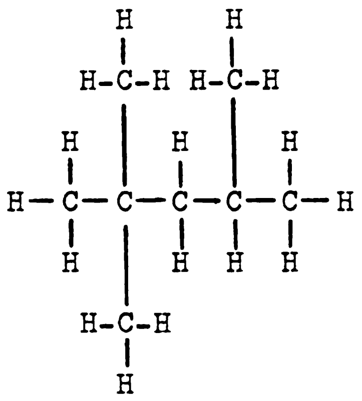
Table 14. The number of chemical bonds which some of the more common elements may form.

Name of Element	Number of Bonds Usually Formed	Representation
Carbon	four	-C- or =C= or -C≡
Hydrogen	one	H-
Oxygen	two	O= or -O-
Chlorine	one	Cl-
Nitrogen	three	-N< or -N= or N≡

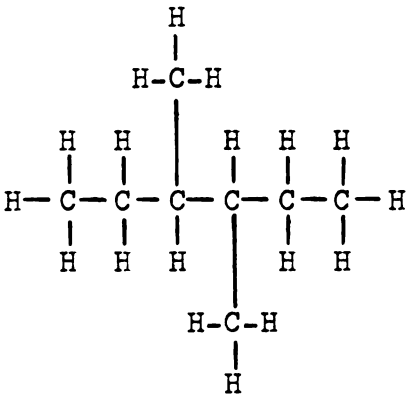
Unlike most other elements, carbon atoms may bond to one another. When this happens, long chains of carbon atoms may result:



This molecule is "octane." Octane, C_8H_{18}, is one of the ingredients of most gasolines. As you might expect, there are other ways in which the same number of carbon and hydrogen atoms may be arranged:



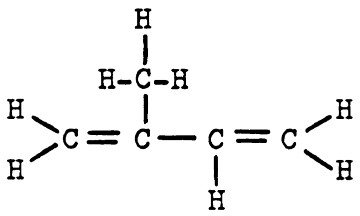
2,2,4-trimethyl pentane



3,4 dimethyl hexane

As a matter of fact, there are fifteen other ways in which eight carbon atoms and eighteen hydrogen atoms can be arranged. Molecules like this, which contain the same number and same kinds of atoms, but which are arranged differently, are called "isomers." Even though they have the same chemical formula, different isomers usually have some properties which are dissimilar from their other isomers.

Under certain conditions, carbon atoms can form two, or even three bonds, with one another. When this happens, we say that the carbon atoms are doubly or triply bonded, or simply that double or triple bonds have formed.



Isoprene

Acetylene

Figure 27. The chemist's representation of double and triple carbon-carbon bonds. Isoprene, a constituent of natural rubber which has two double bonds, is shown on the left. To the right: Acetylene, a gas which is used in the oxyacetylene cutting torch, has a triple bond.

In addition to forming straight or branched chains, carbon atoms may also form closed chains or rings.

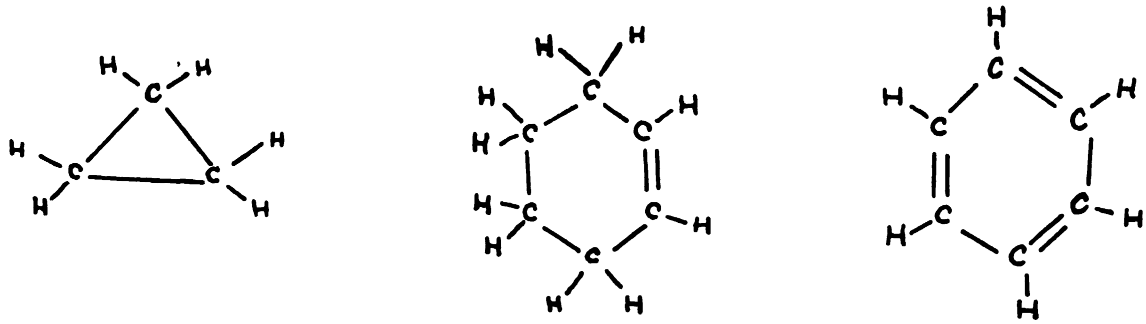


Figure 28. Some carbon compounds which contain closed chains or rings of carbon atoms.

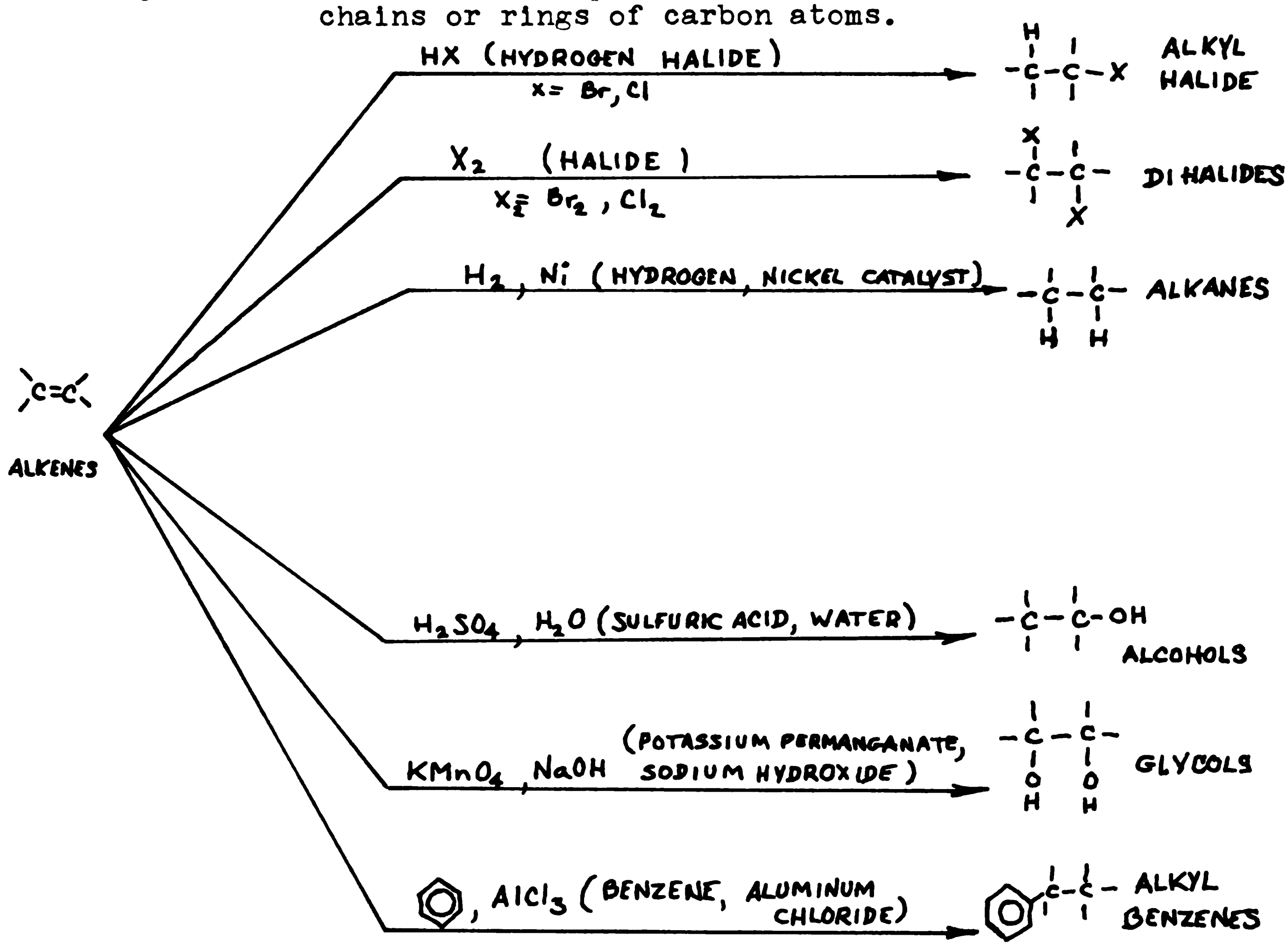


Figure 29. Some of the chemical reactions which characterize the chemical family known as the alkenes. All members of the alkene family have doubly bonded carbon atoms as their major distinctive feature. The presence of this bond causes the members of this family to act as shown. The chemical reagent needed to carry out each reaction is shown above the arrow; the substance produced when this reagent reacts with an alkene is shown to the far right.

With all the infinite possibilities for different molecular arrangements, it is little wonder that millions of carbon compounds exist. Fortunately, the task of identifying an unknown carbon compound is greatly simplified by the fact that the presence of certain groups of atoms and certain types of bonds between carbon atoms result in a limited number of chemical families which have certain characteristic chemical properties.

2.6 Questions and Problems

1. What does the term "chemical properties" mean?

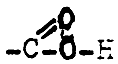
2. Why is a study of the chemical properties of an unknown essential to its identification?

3. Draw representations of the following molecules using symbols to represent atoms and lines to represent chemical bonds: methane, CH_4; methyl chloride, CH_3Cl; water, H_2O; carbon dioxide, CO_2; methyl alcohol, CH_3OH; ethyl alcohol, C_2H_5OH; propane, C_3H_8; and acetic acid, CH_3COOH. Remember that carbon, hydrogen and oxygen have bonding capacities of four, one, and two respectively.

4. There are eighteen ways in which eight carbon atoms and eighteen hydrogen atoms may be arranged. Draw as many of these arrangements as you can.

5. Research indicates that a certain compound is composed entirely of carbon and hydrogen, and that there are 6.00 grams of carbon for every 1.00 gram of hydrogen present. A molecular weight determination shows that the compound has a molecular weight of 42.00. The chemical properties of the unknown indicate that it has one carbon-carbon double bond. What is the actual molecular structure of this compound? The atomic weight of carbon is 12.00 and that of hydrogen is 1.00.

6. An unknown is analyzed and found to consist of 6.00 grams of carbon, 1.00 grams of hydrogen, and 5.33 grams of oxygen. The molecular weight is found to be 74.00. The chemical properties show that the unknown is an organic acid, a family of compounds, all of which contain the group shown below. What is the actual molecular structure of this unknown? Oxygen has an atomic weight of 16.00.



7. Years ago, a very important compound was analyzed and found to contain 12.00 grams of carbon for each 1.00 gram of hydrogen. Further analysis revealed that the compound had a molecular weight of 78.00. No other

elements were present. After this initial research had been done, chemists began to suspect that the compound contained some carbon-carbon double bonds. However, the chemical properties of the unknown compound were not exactly the same as those of compounds known to contain double bonds. Can you devise a molecular structure that is consistent with this information, yet utilizes double bonds in a slightly different way?

8. Analysis of an unknown shows that it contains only carbon, hydrogen and oxygen. For each 1.00 grams of hydrogen there are 10.00 grams of carbon and 13.33 grams of oxygen. A study of the chemical properties of the unknown shows that it has two acid groups and one ketone group per molecule. The molecular weight is 146. What is the actual molecular structure of this keto-acid?

```
                    O                                   O
                   //                                   ||
acid group     -C-O-H          ketone group          -C-
```

9. Naphthalene is known to contain only carbon and hydrogen. For each 1.00 gram of hydrogen, there are 9.60 grams of carbon. The molecular weight of naphthalene is 106. Its chemical properties are very much like those of benzene. What is the actual molecular structure of naphthalene?

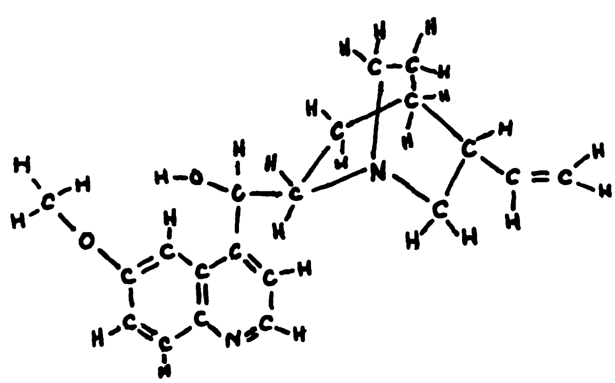
2.7 Developing Drugs to Fight Disease: Step (8) Degradation of the Unknown

Let's briefly review what has taken place in our attempt to reproduce in the laboratory naturally occurring drugs such as quinine. First, an accidental discovery is made that a substance such as cinchona bark has curative powers. Next, chemists attempt to separate the compound which is responsible for the curative powers from the accompanying inert ingredients. Once the compound responsible for the curative powers--the active ingredient--has been isolated, the chemist begins a thorough study of it. The chemist determines which elements are present in the compound, the molecular weight of the compound, and its simplest chemical formula. The chemist also determines the physical and chemical properties of the compound.

Knowledge of the chemical properties of the unknown compound often reveals the chemical family to which the unknown compound belongs. Suppose, for example, all the data collected indicates that our unknown compound belongs to the chemical family known as the "aldehydes." Now, the question which the chemist must answer is, "What aldehyde is the unknown compound?" Armed with data concerning the melting point, the density, and other physical properties, the chemist turns to the chemical literature which lists the properties of all of the known aldehydes.

If his search of the literature reveals an aldehyde whose physical properties closely correspond to those of the unknown compound, the chances are good that the two compounds are the same. If this happens, the chemist has been very lucky, because now all that he has to do to confirm the identity of the unknown compound is to carry out a reaction which will convert the unknown compound into another, similar compound. Then, the same reaction is carried out with the aldehyde previously found in the literature whose properties corresponded to those of the unknown compound. If both reactions result in formation of the same compound, the chemist accepts this as confirmation that the unknown compound and the aldehyde found in the literature are identical.

Now, what must the chemist do if his search of the literature fails to reveal an aldehyde having the same properties as our unknown? In this case, the unknown must be a new compound which chemists have never seen before. To determine the structure of this new compound, the chemist begins to carefully break the unknown molecule apart, one group at a time. This is done chemically, of course. Such a procedure is known as "degradation." As each fragment of the molecule is removed, the chemist tries to identify it. Later, when most of the unknown molecule has been chemically degraded, and the fragments have been identified, the chemist tries to figure out what the structure of the unknown must have been. When the chemist thinks he knows the structure of the unknown, he attempts to verify his previous guesswork by making the compound in the laboratory in such a way that he can be sure of its structure. If the compound which he makes has properties like those of the unknown, this is usually taken as proof that the two molecular structures are identical.



The quinine molecule

Figure 30. The structure of quinine. The carbon-carbon rings at the lower left were discovered in early degradations, and the other structural details were added over nearly a twenty-five year period of time.

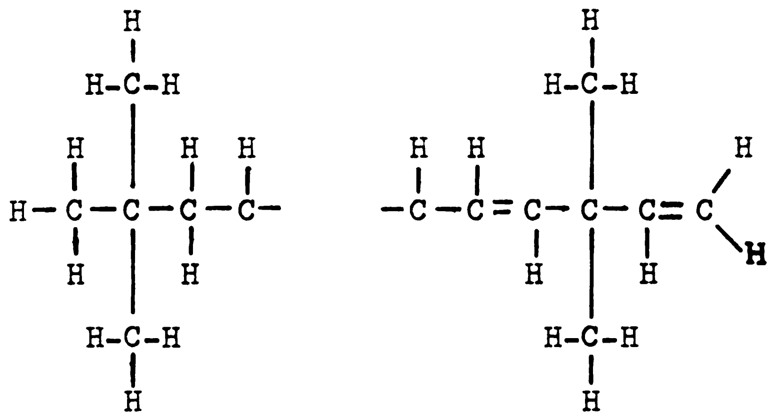
Although quinine was isolated as early as 1820, its structure was not worked out until 1908. The correct structure came about only after twenty-five years of degradative work by almost a dozen chemists.

2.7 Questions and Problems

1. What does the phrase, "degradation of the unknown," mean?

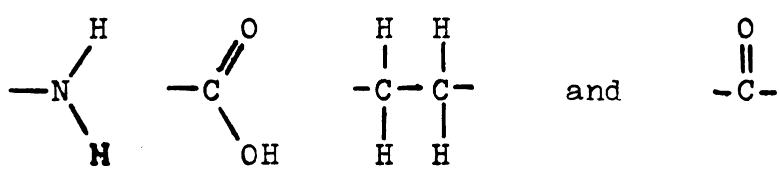
2. When is degradation necessary?

3. Laboratory work reveals that an unknown has the actual formula $C_{14}H_{24}$. Degradative work indicates that these two groups of atoms are present in the unknown:



What is the complete molecular structure of the unknown?

4. Degradative and other laboratory work reveals that an unknown consists of the following groups of atoms:



Draw all of the molecular structures which are consistent with this data.

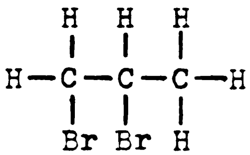
5. In question 4, you found that more than one molecular structure was possible. What might chemists do to help them decide which structure was actually the correct one?

2.8 Developing Drugs to Fight Disease: Step (9) The Synthesis of Compounds

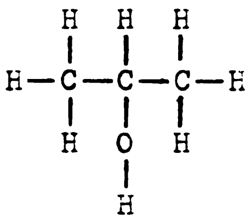
All of the chemist's efforts thus far have been directed toward the ultimate goal of duplicating the active ingredient of a naturally occurring drug. However, once the chemist has gained knowledge of the molecular structure of the active ingredient, he can begin to chemically build the desired molecular structure. The process of building molecules from simpler substances is called "synthesis."

On paper, the synthesis of a given molecule may appear to be a very easy task. However, this is seldom the case. First, the chemist must carefully plan the route which his synthesis will take. To do this, the chemist relies on his hard-earned knowledge of the subject, plus what he can unearth in chemical libraries about the reaction which he wishes to carry out. Since we lack the knowledge which the chemist has, we shall discuss only a few very simple syntheses, and we shall make use of a "flow sheet" such as is shown in Figure 31.

In the remainder of this section, we shall take a look at the synthesis of several simple molecules. The first synthesis that we shall consider is that of 1,2-dibromo propane. This molecule has the following structure:



As a raw material from which to make this molecule we have isopropyl alcohol, a secondary alcohol which has this structure:



We also have access to the other reagents which will be needed to convert isopropyl alcohol to 1,2-dibromo propane, of course.

To plan our synthesis of 1,2-dibromo propane, we turn to the following flow sheet. This diagram reveals several facts which are pertinent to our synthesis:

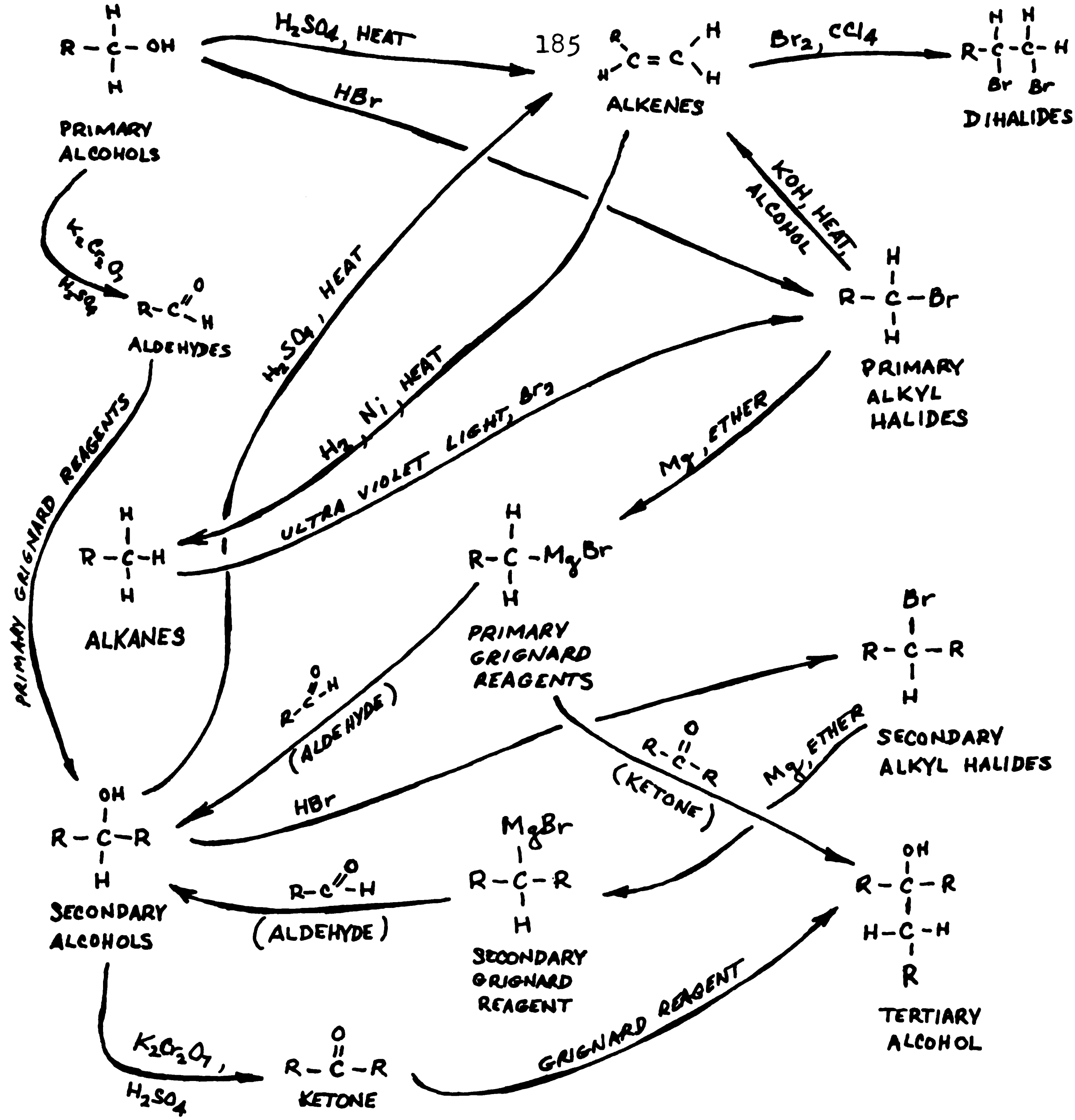
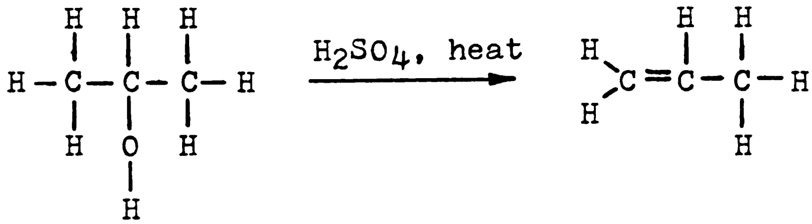
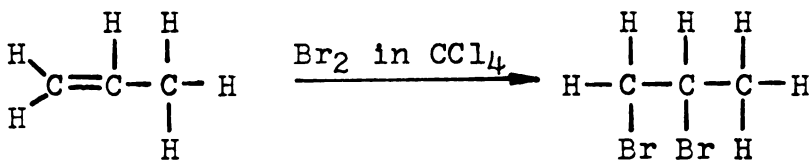


Figure 31. A "flow sheet" showing only a few of the thousands of known chemical reactions. This diagram shows some of the reactions which a chemist might utilize in the construction of a sequential series of reactions which might result in the laboratory production of a valuable compound. The letter "R" is used to represent a chain of carbon and hydrogen atoms of unspecified length. The reagents needed to bring about each conversion are shown above the arrows.

(1) When secondary alcohols are heated in the presence of sulfuric acid, H_2SO_4, they lose H and OH and form a double bond:



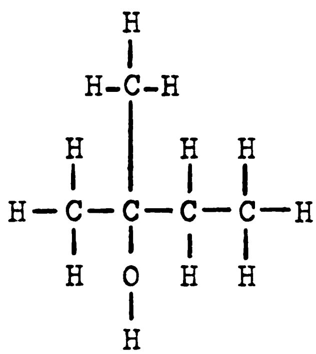
(2) If bromine, Br_2, in a carbon tetrachloride, CCl_4, medium is added to a compound which contains carbon-carbon double bonds, bromine atoms attack the double bond and add on to the molecule at both ends of the double bond:



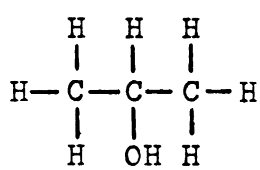
1,2-dibromo propane

This has been a simple, two step synthesis. Most syntheses are considerably more complicated, and may involve many steps.

As a second example of chemical synthesis, suppose that we wished to make 2-methyl-2-butanol, a secondary alcohol having this structure:



As raw materials from which to make 2-methyl-2-butanol, we shall use ethyl alcohol, a primary alcohol having the formula, C_2H_5OH, and isopropyl alcohol,

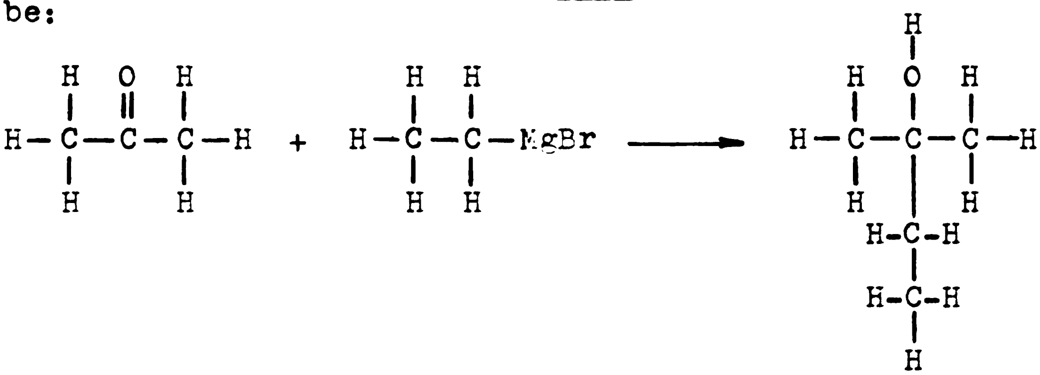


plus whatever reagents will be needed to convert these two substances into 2-methyl-2-butanol.

(Before reading the following explanation of how 2-methyl-2-butanol can be synthesized from ethyl alcohol and isopropyl alcohol, you might want to try to figure the synthesis out for yourself. Or, perhaps you might want to read part of the explanation, and then attempt to complete the synthesis on your own before reading the remainder of the explanation.)

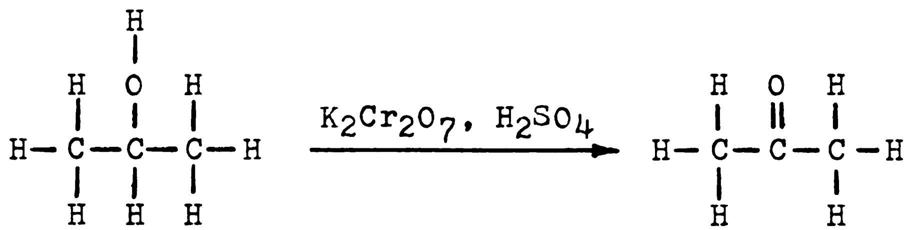
We begin our synthesis of 2-methyl-2-butanol by studying the flow sheet provided earlier. Since both ethyl alcohol and isopropyl alcohol have fewer carbon atoms in their carbon chains than does 2-methyl-2-butanol, it is likely that we shall have to find some way of joining ethyl alcohol and isopropyl alcohol into a new, longer chain of carbon atoms. Furthermore, since our flow sheet shows no reaction which describes the joining of two alcohols, it is likely that one--or possibly both--alcohols will have to be changed into some form of intermediate species before the two carbon chains can be joined together. When faced with a complicated synthesis such as this, chemists generally work backwards; that is, they start by asking themselves, "What reagents are needed to make the last step in this synthesis?" The last step is the one which results in the ultimate end product, of course. Next, the chemist tries to figure out how to make the reagents needed for the last step. He continues this procedure, moving backwards one step at a time, until his synthesis begins with the raw materials from which he planned to start.

By studying the flow sheet carefully, we find that a Grignard reagent will react with a ketone to form an alcohol with a branched structure like the one which we wish to make. This implies that the <u>last</u> step in our synthesis will be:

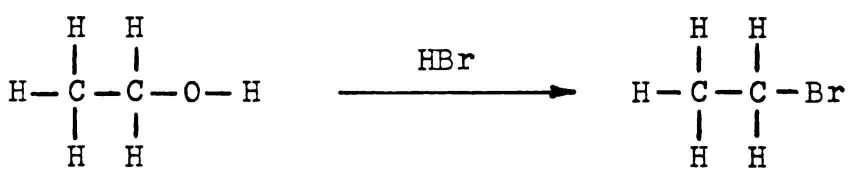


dimethyl ketone   Grignard reagent   2-methyl-2-butanol, a tertiary alcohol

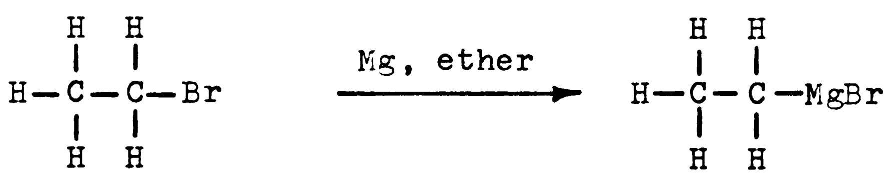
Our next problem is one of deciding how to make the ketone and Grignard reagent called for by the preceding reaction. Again, we study the flow sheet, looking for a reaction which will convert our raw materials--both alcohols--into a ketone and a Grignard reagent. Careful study reveals a reaction which will convert a secondary alcohol into a ketone:



Further study reveals a pair of reactions which will enable us to convert an alcohol into a Grignard reagent:

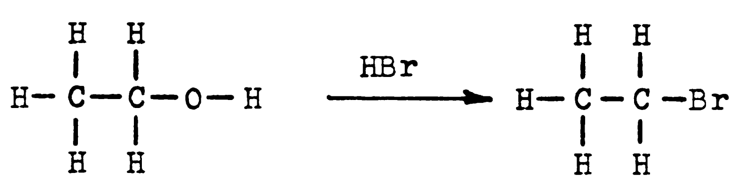


and,

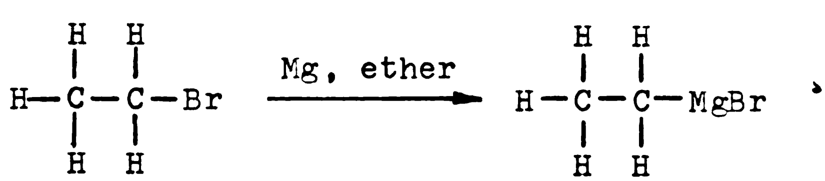


When all of these steps are arranged in the sequence in which they would actually be carried out, the complete synthesis becomes:

Step (1) Convert ethyl alcohol in an alkyl halide and then to a Grignard reagent:

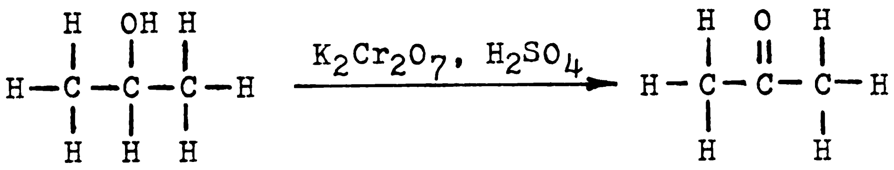


and,



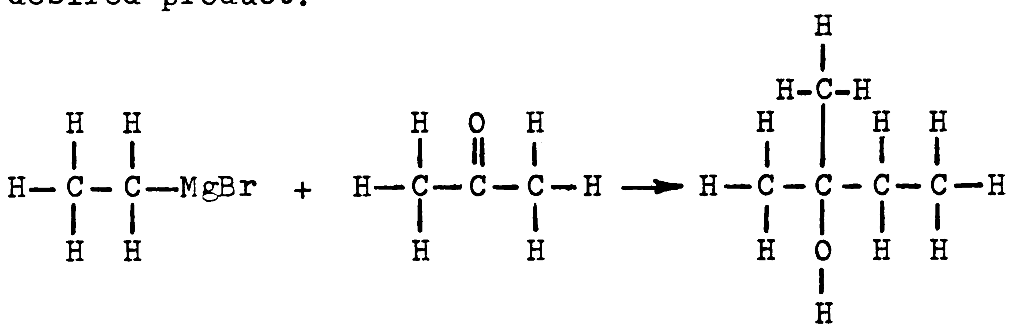
Grignard reagent

Step (2) Convert isopropyl alcohol into ketone:



ketone

Step (3) React Grignard reagent with ketone forming desired product:



2-methyl-2-butanol

Generally speaking, the two substances whose synthesis we have discussed are simpler than most of those prepared by organic chemists. However, you must remember that the organic chemist has had many years of training and experience: He is a specialist in a deep, complex field.

Are all new drugs simply exact copies of naturally occurring medicines? Many new drugs are either exact copies or are directly related to some naturally occurring medicine; only a very few are not related. Before a chemist can make a compound which promises to be useful in the battle against disease, he has to decide what sort of a molecular structure to make. Were he simply to pick out a molecular structure at random, synthesize it, and then test it against certain diseases, he might end up making thousands and thousands of compounds before stumbling across a compound which proved to be of value in the battle against disease.

To avoid such a time-consuming, wasteful, hit-or-miss approach, chemists usually try to synthesize molecular structures which have some of the same features as compounds which have previously proven their value. For example, if you study the structure of quinine, which had been used since the 1600s, and compare it with the anti-malarial drug, plasmochin, which was produced by German chemists in 1926, you will see that both compounds are quite similar. This similarity is by design rather than accident: The German chemists used the quinine structure as a starting point for their synthesis of plasmochin.

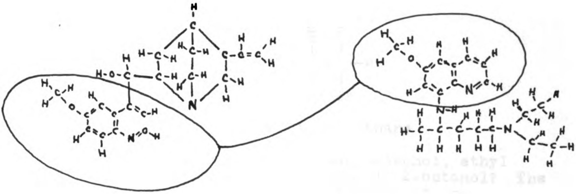
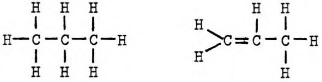


Figure 32. The molecular structure of quinine and plasmochin. Left: The molecular structure of quinine. Right: The molecular structure of plasmochin, an anti-malarial drug patterned after quinine. Note the similarity of the circled sections of both molecules.

2.8 Questions and Problems

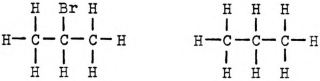
1. Describe a synthesis which will enable a chemist to convert the alkane, propane, C_3H_8, into the alkene, 1-propene, C_3H_6. The molecular structures involved are:



propane 1-propene

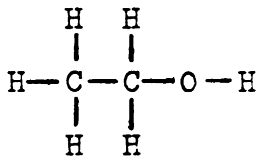
Consult the flow sheet provided in this section for help in planning your synthesis. You may utilize any reagents called for on the flow sheet, of course.

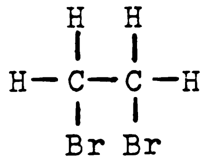
2. How would you go about converting the secondary alkyl halide, 2-bromo propane into the alkane, propane? The molecular structures involved are:



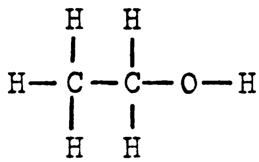
2-bromo propane propane

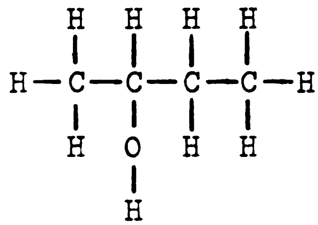
3. Design a synthesis which will convert the primary alcohol, ethyl alcohol, into the dihalide, dibromo ethane. The molecular structure of these substances follow:


ethyl alcohol

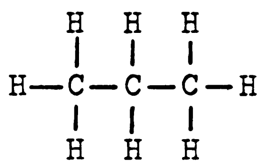

dibromo ethane

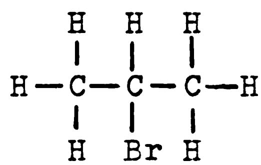
4. How would you convert the primary alcohol, ethyl alcohol, into the secondary alcohol, 2-butanol? The molecular structures of these substances are:


ethyl alcohol

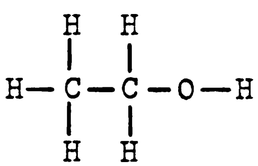

2-butanol

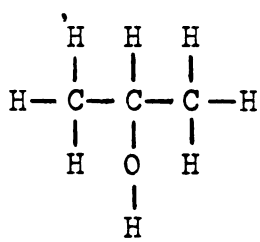
5. Design a synthesis which will enable you to convert the alkane, propane, into the dihalide, 2-bromo propane. (Hint: It is not possible to do this directly using bromine and ultraviolet light.)

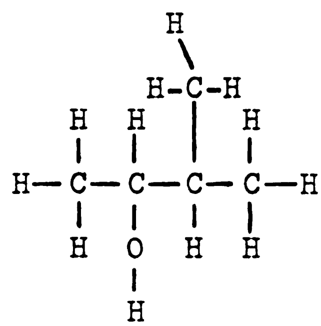

propane


2-bromo propane

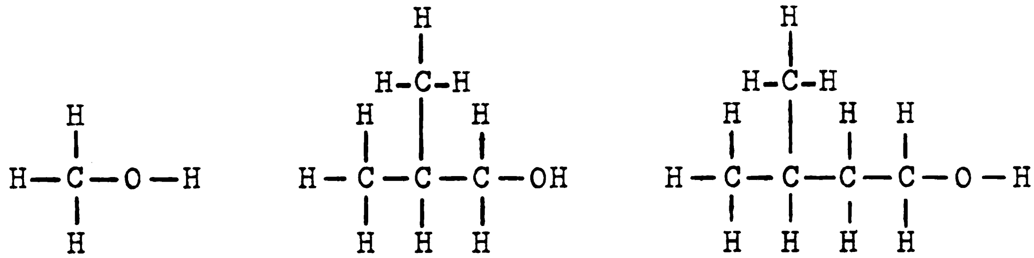
6. How would you synthesize the secondary alcohol, 3-methyl-2-butanol from the primary alcohols, ethyl alcohol and isopropyl alcohol? The molecular structures of these substances follow:


ethyl alcohol


isopropyl alcohol


3-methyl-2-butanol

7. Design a synthesis in which the primary alcohols, methyl alcohol and 2-methyl propanol are used to synthesize the primary alcohol, 2-methyl-1-butanol. The molecular structures are:



methyl alcohol | 2-methyl propanol | 2-methyl-1-butanol

2.9 The Impact of the Organic Chemist on World Affairs

Although the work of the organic chemist may seem somewhat removed from the mainstream of civilization, this is not the case. In only a few short years, the products synthesized by the organic chemist have altered the lives of millions of people. We can illustrate the impact which the science of organic chemistry has had on civilization by reviewing the history of malaria.

As you know, malaria has plagued mankind for hundreds of years. By the late 1940s, malaria was the number one killer of men. Of the six and one-half million people on earth who died each year, malaria claimed over three and one-half million. With the development of more effective insecticides such as DDT, the incidence of malaria diminished all over the world. Within a few short years, death rates in many countries dropped at fantastic rates as millions of people who would have died of malaria lived. For example, in tropical Ceylon, spraying with DDT decreased the overall death rate from 20 to 14 deaths per 1000 people in a single year, 1946-1947. Earlier, it had taken England nearly half a century to decrease its death rate this much.

Although death rates diminished, birth rates around the world remained steady. By the late 1960s death rates were so much lower than birth rates that the population of the earth was increasing at the rate of about 1½ million people a week. Experts predicted that the earth's population would double from 3½ billion people to 7 billion people in less than thirty years. As civilization headed into the 1970s, over 2/3 of the world's people were facing a population explosion which had been brought about largely by the development and use of DDT.

Soon it became apparent that death by starvation was claiming almost the same number of people formerly claimed by malaria. In 1966, India narrowly sidestepped massive famine when the U. S. sent over one-quarter of its entire wheat crop to that country. As the struggle to keep the earth's increasing millions fed intensified, so did the use of DDT as an agricultural pesticide. However, soon it became evident that the higher animals and man absorbed large concentrations of poisonous DDT in their tissues. This presented man with a cruel dilemma: If he outlawed the use of DDT in order to prevent its build-up, he ran the risk of letting malaria re-establish itself. Adding to the complexity of the whole problem was the somber fact that insects usually eat one-third of each year's food crop. If the food eaten by insects was available to feed humans, starvation would no longer be an immediate threat to over one-half of mankind, as it is today.

Plainly, one of the things that the situation called for was more efficient, more selective insecticides. But, before such insecticides could be developed, chemists needed more knowledge than they possessed. For example, while chemists knew that a certain molecular structure was poisonous to insects, they seldom knew why one structure--and few others--was effective. Once chemists possessed this knowledge, it might be possible to better tailor molecules to kill a specific insect without having the insecticide be harmful to other living organisms. As in the past, man's ability to solve problems was once again sharply limited by his lack of knowledge.

2.9 Questions and Problems

1. Briefly outline the effect that malaria has had on the course of human events over the last fifty years.

2. It is often argued that mankind would be better off had DDT never been discovered. Do you agree or disagree with this statement? Explain.

2.10 A Comment Concerning the Value of Our Endeavor

Perhaps, as you read the preceding pages you wondered: If malaria is no longer a problem in the U. S., why should we bother to learn about it? While it is true that malaria has disappeared from the U. S., there are a number of excellent reasons for our having studied the history of this disease.

Generally speaking, one of the major purposes of education is to help develop people who will be assets--rather than liabilities--to society. One of the characteristics which makes an educated person an asset to society is the fact that he is able to look at things with a broader, more enlightened viewpoint. One of the reasons that an educated person has this sort of a viewpoint is that he knows what has been valuable to society in the past. For example, past experience has shown that if society wishes to avoid suffering, it must gain control over diseases such as malaria. To gain this control, man must not only study these diseases, but he must also study other scientific activities which may not seem to be related to disease. For example, in order to isolate quinine, man had to know something about separation techniques; and, in order to synthesize complex molecular structures like the quinine substitutes and DDT, it was necessary to learn how to determine molecular weights, melting points, and a whole host of other physical and chemical properties.

To the uneducated person, there may seem to be little connection between the melting point of a substance and a terrible disease such as malaria, but as you know, a knowledge of melting points may play an important role in the identification of a compound of unknown composition.

This same principle extends to other branches of science. If man wishes to gain control over nature, he must study it. Since this study often involves costly research and training, society must be prepared to pay for the cost of these activities if our lives are to improve. Since you have an understanding of the subtle relationship between scientific knowledge and the prevalence of disease, you should place greater value on scientific research than does someone who lacks this insight. In turn, this outlook should make you a greater asset to society than someone who takes a negative view of scientific research. You might think that perhaps most adults are aware of the value of scientific research; but, unfortunately, this is not the case. For example, arthritis, which often so cripples people that they are unable to use their hands, annually prevents thirteen million people from earning their own living. It has been estimated that each dollar invested in arthritis research returns almost forty dollars in added earnings to the national income. Yet, despite this very favorable, proven return on the original investment, arthritis research workers often must beg for financial support, and much needed research is not done because of lack of financial support.

Entirely from a financial standpoint, it would be very advantageous for us to accelerate the rate of medical research. Like arthritis research, most medical research has a very favorable rate of return because it is far cheaper to prevent disease than it is to treat it or support those who are unable to work as a result of being stricken by disease. With increased research we could learn why the heart fails to beat, or why blood sometimes forms clots in the arteries of older people. At present, neither of these things are very well understood, yet they must be known if we are to stop heart disease. At present, heart disease kills more people in the U. S. than does all other diseases combined. Only when many people realize the role that scientific research plays in the prevention of disease will people no longer die and be crippled by preventable or controllable diseases.

2.10 Questions and Problems

1. Explain the relationship which exists between a disease like malaria and a separation process such as filtration.

2. How can mankind best gain control over nature?

3. In many communities the per pupil cost of education often approaches one thousand dollars per year. This means that by the time a student graduates from high school, a community may have invested $12,000 in this student's education. Why is society willing to make an expenditure like this?