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A Review of the Status of the Teaching of Genetics and Evolution in High School Biology Courses with Suggestions for Improving the Teaching of These Subjects

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A REVIEW OF THE STATUS OF
THE TEACHING OF GENETICS AND EVOLUTION
IN HIGH SCHOOL BIOLOGY COURSES WITH SUGGESTIONS
FOR IMPROVING THE TEACHING OF
THESE SUBJECTS

A THESIS
PRESENTED TO
THE FACULTY OF THE SCHOOL OF GRADUATE STUDIES
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OF THE REQUIREMENT FOR THE DEGREE OF
MASTER OF ARTS

by

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# TABLE OF CONTENTS

**ACKNOWLEDGEMENTS** ................................................................. 1

**INTRODUCTION** ............................................................................. 111

**CHAPTER**

I. **THE ROLE OF THE UNIFYING CONCEPTS OF BIOLOGY IN PROVIDING A LIBERAL EDUCATION** ................................................................. 1

II. **THE IMPORTANCE OF GENETICS AND EVOLUTION IN HIGH SCHOOL BIOLOGY** ................................................................. 7

III. **OBJECTIVES IN TEACHING GENETICS AND EVOLUTION** ......... 10

IV. **THE STATUS OF GENETICS AND EVOLUTION TEACHING AT THE HIGH SCHOOL LEVEL** ................................................................. 20

\[ \text{The problem of religious opposition to the teaching of evolution} \] 25

\[ \text{The problem of lack of knowledge on the part of the teacher} \] 42

\[ \text{The problem of inadequate textbooks} \] 50

V. **CONCLUSION** ............................................................................. 56

**APPENDICES**

I. **A SELECTED ANNOTATED BIBLIOGRAPHY OF REFERENCE BOOKS ON GENETICS AND EVOLUTION** ................................................................. 58

II. **A SELECTED BIBLIOGRAPHY OF ARTICLES IN PERIODICALS ON GENETICS AND EVOLUTION** ................................................................. 75

III. **SOURCES OF INFORMATION CONCERNING THE PLANNING OF LABORATORY EXPERIENCES IN GENETICS AT THE HIGH SCHOOL LEVEL** ................................................................. 107

IV. **A SELECTED BIBLIOGRAPHY OF ARTICLES ON THE NEO-DARWINIAN CONCEPT OF EVOLUTION** ................................................................. 110

V. **A SELECTED LIST OF FILMS ON GENETICS AND EVOLUTION** ................................................................. 113
INTRODUCTION

It is the purpose of this thesis to: (1) discuss the place of genetics and evolution in high school biology courses; (2) specify the objectives that should be attained in teaching genetics and evolution; (3) discuss the current status of the teaching of genetics and evolution in high school biology courses; and (4) suggest means of overcoming the three problems which have resulted in the poor teaching of genetics and evolution on the high school level—first, the problem of religious opposition to the teaching of evolution; second, the problem of a lack of knowledge on the part of the teacher; and third, the problem of inadequate textbooks.

The writer has prepared five bibliographies which are designed to help the teacher improve his teaching of genetics and evolution. These bibliographies have been placed in appendices because their length would tend to disrupt the pattern of thought in the main body of the thesis. They are, nonetheless, very pertinent to the thesis and constitute a large portion of the work done by the writer in preparing the thesis.
Chapter I

THE ROLE OF THE UNIFYING CONCEPTS OF BIOLOGY IN PROVIDING A LIBERAL EDUCATION

There are four major unifying concepts in biology: (1) the structural and chemical basis of living matter (cellular biology), (2) interrelations of living organisms and their environment (ecology), (3) the genetic basis of inheritance (genetics), and (4) organic change through natural selection (evolution). These unifying concepts constitute the framework which holds together the disciplines of biology. These concepts have tended to create order out of the great quantity of biological knowledge. Each of these concepts provides the student with a different point from which he can look at the vast field of biology and see the relationships that exist among its many seemingly unrelated disciplines.

The teaching of these unifying concepts in high school biology will help the student acquire a liberal education. The liberal aspect of education which produces truly free men and women in a democratic society has largely been neglected by high school biology teachers. The vocational and professional areas of biology have been overemphasized at all educational levels to such an extent that the end products of this education are technicians with a narrow or
extremely circumscribed vision of science. A knowledge of the unifying concepts of biology enables the student to enlarge his comprehension of the natural world and of man's place in it. This is one of the goals of a liberal education.

Bentley Glass, in his book Science and Liberal Education, says this about the teaching of science as a part of a liberal education:

In teaching science we must not forget... that it is simultaneously social study and creative art, a history of ideas, a philosophy, and a supreme product of esthetic ingenuity. The graduate who has missed this experience, whether science major or non-major, has missed the basis for a rational judgment of today's crucial problems. He has also lost a revelation deep in meaning and of unending beauty.

The relationships that exist between biology, geology, chemistry, physics, mathematics and the humanities can clearly be demonstrated when teaching the unifying concepts of biology. Science teachers, in both high school and college, have been criticized justly for teaching the "cold facts" of science without relating them to social studies and the humanities. Science teachers would do well to remember that science, politics, philosophy, and religion do not exist in separate compartments, but interact in many ways. It is the opinion of the writer that the application of scientific principles to man should be discussed

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in the classroom whenever such a discussion will increase the student's comprehension of the world and man's place in it. Such discussions should help the student comprehend the fact that man is a part of nature, rather than being separate from nature and not describable in terms of the same laws that describe the actions of the rest of nature. Students must be made aware of the fact that science has not only provided for the physical needs of man but also has contributed to man's concept of his place in the universe.

The four unifying concepts of biology encompassed by the fields of cellular biology, ecology, genetics, and evolution can and must be made a part of the liberal education of every student who studies biology in high school. Yet, in spite of the educational value of these four unifying concepts, biology instructors generally have failed to reorganize the traditional disciplines around these important concepts. Why has the use of these unifying concepts in biology teaching been so retarded? Why is it that most secondary school biology courses or, for that matter, most college freshman biology courses are still mainly taxonomic in approach and content, loading the student with rote memorization while treating the major unifying concepts superficially or omitting one or more of them altogether? The writer believes that there are at least three reasons for the neglect of these unifying concepts by those involved
in the teaching of biology.

First, the four unifying concepts have only recently been made the basis for full fledged disciplines in biology. That is to say, these concepts have only recently been delineated and clarified. The body of knowledge encompassed by these unifying concepts has become voluminous within the past few decades. Because of this, many biology teachers, unable to keep up with the recent advances in these new areas of biology, have not realized the importance of these concepts nor their value to the student acquiring an education in biology.

Second, the unifying concepts still are being treated as "step-children" by many biology departments in colleges. This is due in part to a lack of up-to-date knowledge in these areas on the part of college instructors, and also to the fact that most of the biologists teaching in colleges and universities have specialized in relatively restricted areas, and being primarily interested in these areas, overemphasize them to the detriment of the unifying concepts. Most of the biology courses offered on the college level are still predominantly descriptive in character and involve the memorization of taxonomic nomenclature and other specialized terminology. The education of prospective biology teachers in the four unifying concepts is very deficient as a result of inadequate course offerings in these areas and the nonrequirement of such courses for students preparing
to teach biology. In view of the education that most biology teachers, present and prospective, receive it is little wonder that they overemphasize the taxonomic approach and stress rote memorization by the type of subject matter they present to their students.

Third, the over stressing of the argument that students need a background in taxonomic biology before they can comprehend the four unifying concepts has retarded the use of these concepts by teachers of high school biology. The memorisation of detailed biological information has been, and is being, carried to extremes. One must realise that the disjunct pieces of information taught in such courses will not "fall into place for the student" but rather soon will be forgotten unless the student has been brought to an understanding of the four unifying concepts which will enable him to create an organized pattern out of the chaotic mass of information that he has acquired.

Biologists are just beginning to realise the value that these four unifying concepts have in terms of helping the student acquire a liberal education. The high school biology course which stresses taxonomy along with human anatomy and physiology is being attacked on a grand scale by the American Institute of Biological Sciences. The AIBS, through its high school curriculum study committees, is attempting to reorganize high school biology curricula. The AIBS film series, \(^2\) which

is designed for tenth grade biology, has devoted 46 of the 120 film-series to the teaching of the four unifying concepts and also utilizes these concepts as continuing themes to be emphasized throughout the entire film series. The AIBS Biological Sciences Curriculum Study (BSCS)\(^3\) has prepared three types of tenth grade biology courses, all of which place increased emphasis on the unifying concepts of biology as opposed to the traditional biology course which emphasizes taxonomy, human anatomy, and human physiology to the virtual exclusion of the four unifying concepts.

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Chapter II

THE IMPORTANCE OF GENETICS AND EVOLUTION IN HIGH SCHOOL BIOLOGY

Laba and Gross have stated that "The concepts of organic evolution and genetics bear the same relation to the biological sciences as the atomic-molecular theory and the laws of conservation of matter and energy bear toward the physical sciences." 

4 The neo-Darwinian concept of evolution is based on the genetic phenomena of mutations, and genetic recombination (sexual reproduction), together with natural selection and isolation (geographic and/or reproductive). This concept has woven genetics and evolution so tightly together that evolution can now be explained in terms of population genetics plus the factors of time and natural selection. The neo-Darwinian concept of evolution, by interrelating genetics and evolution, has given new meaning to these disciplines—a new meaning that is just beginning to be understood by the disciplines outside of science.

A thorough understanding of genetics and evolution will expose the student to a new way of looking at life—a new way of looking at nature and man's place in nature. This is pointed out by Ehrle:

There are essentially two major ways in which
the living world can be viewed with respect to
time. It can be considered to be static, un-
changing, and fixed. Species are immutable and
the life that exists now is much like the life
that has existed in the past and will probably
continue to exist into the future. As an alter-
native, life can be considered to be dynamic,
everchanging, and in a continuous state of de-
velopment. Species are relatively plastic and
transitory, and the life which existed in the
past is very different from that which exists
now, as well as from that which will exist in
the future. The choice is not a difficult one.
The entire essence of life itself bespeaks of
change, this continuous newness of life, this
unfolding, is the fact of evolution.

An understanding of genetics and evolution, then, will
be an aid in helping the student to formulate his personal
philosophy, and in helping him to acquire a better under-
standing of life itself.

The very survival of man on the earth may well depend
upon whether or not he acquires an understanding of evol-
utionary forces and their application to mankind. The prob-
lems of race, of mutation (whether natural or induced by
man), of competition, of overpopulation, and of the social
control of man’s evolution can be understood and dealt with
adequately only if mankind has acquired an understanding of
how the various evolutionary forces operate. The importance
of mankind’s possession of knowledge concerning the mechan-
isms of evolution is stressed by Hardin:

5. E. Ehrle, "Notes on the Teaching of Evolution," The Amer-
It doesn't much matter whether you think man was created out of the dust six thousand years ago or came from the apes a million years earlier, whether the story of Noah's Ark is true, or dinosaurs once lived. Believe what you will of evolution of the past but you had better believe it will take place in the future if you hope to make political decisions that will give your descendants a reasonable chance to exist. The principles of evolution are inescapably relevant to the analysis of man's predicament.

Genetics and evolution provide a major part of the basic framework holding the many and varied disciplines of biology together. As such, their value in any study of biology cannot be overestimated. The importance of their role in providing an education in biology is attested to by Laba and Gross:

The theories of organic evolution and the theory of the gene are of profound significance in the biological sciences. Together they provide the twin pillars upon which rest the entire edifice of zoology, botany, paleontology, and human anatomy and physiology. Conversely, the absence or deletion of these theories from the study of biology would make the detailed observations about living things pointless and fragmentary.

In the pages that follow, the writer has attempted to clarify the major objectives to be reached when teaching genetics and evolution, and to suggest ways to enhance the status of the teaching of genetics and evolution in biology courses on the high school level.

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7. E. Laba and E. Gross, loc. cit.
Chapter III

OBJECTIVES IN THE TEACHING OF GENETICS AND EVOLUTION

The major objectives which should be attained in the teaching of genetics and evolution, and which are discussed in this chapter, are not limited to introductory high school biology but apply equally as well to advanced high school and college general biology courses, especially those designed for a general education program. These objectives, while seeming to be very general, are in reality all that a teacher should be trying to attain when teaching genetics and evolution. The extent to which these objectives are reached depends on four variables—the teacher, the amount of subject matter covered, the experiences given the student, and the level of intellectual maturity of the student.

The personal views that the teacher holds concerning genetics and evolution may affect greatly the teaching of these concepts (see Chapter IV). The teacher no longer can afford to present a superficial coverage of the subject matter encompassed by genetics and evolution. The teacher who does not provide students with an adequate knowledge of genetics and evolution no longer can feel that he is providing his students with an understanding of the necessary principles of biology that will equip them to comprehend or deal adequately with everyday problems that are partly or completely
of a biological nature.

The type of experiences given the student can play a tremendous role in determining the extent to which the objectives are reached. Field trips and films, as well as laboratory experiments, can be utilised to give the student experiences in genetics and evolution that will help him to associate these concepts with concrete situations.

The problem of the level of intellectual maturity of the student may be a very important obstacle to the student's complete comprehension of the principles of genetics and evolution. Unfortunately, no studies ever have been made to determine the relationship between the level of intellectual maturity of the student and the comprehension of the principles of genetics and evolution. This is an area in which research is desperately needed. It would seem, however, that the subject matter of genetics and evolution can be adjusted to fit the level of intellectual maturity of the student, thus enabling him to gain at least some comprehension of the major principles involved. The problem, then, is how much genetics and evolution can be taught, rather than whether or not it can be taught at all.

The following is a list of the major objectives that are desirable to attain when teaching genetics and evolution in high school. A short discussion follows the statement of each objective.
OBJECTIVE I. TO HELP THE STUDENT ACQUIRE A SCIENTIFIC ATTITUDE TOWARD GENETICS AND EVOLUTION.

The major objective in the teaching of any science should be that of helping the student acquire a scientific attitude—a way of looking at the natural world. There are two philosophical assumptions which seem to be inherent in the scientific attitude—first, the universe, as a whole, displays order; and second, man has reached a sufficiently advanced stage in his own development to examine, interpret, and understand that order. These two philosophical assumptions have been upheld time and time again by the consistent nature of scientific discoveries which have elucidated natural laws.

The student’s acquisition of a scientific attitude concerning genetics and evolution is extremely important if he is to be able to deal adequately with such problems as racism, overpopulation, and the conflict existing between the science of evolutionary biology and certain Judeo-Christian doctrines. Too often the student acquires a scientific attitude which he utilises when studying the physical sciences, but shelves completely when studying biological phenomena that directly or indirectly affect man’s concept of the natural world and man’s place in it. The teacher must make a concerted effort to insure that the student acquires a scientific attitude that he will apply to biological phenomena
as well as to physical phenomena.

There never have been any studies made, to the writer's knowledge, of how various methods of teaching genetics and evolution affect the development of scientific attitudes in high school students concerning these fields. This is equally true of the selection of subject matter content. An investigator desiring to determine what factors affect the development of scientific attitudes concerning genetics and evolution on the part of the student will find the work done by Barkley, 8 Dudycha, 9 Bond, 10 Bond and Sundquist, 11


10 A. Bond, "Experiment in the teaching of genetics, with special reference to objectives of general education," Science Education 24 (February, 1940), 67-72.


12 A. Bond and L. Sundquist, "Study of permanence in learning selected material from the field of genetics," Science Education 24 (November, 1940), 312-314.
Ralya and Ralya,13 and Thurstone14 helpful in planning the experimental design of such a research project.

In summary, the teacher must make a concerted effort to insure that the student develops a scientific attitude toward genetics and evolution. The student must be made aware of what the scientific attitude is, the philosophical assumptions inherent in the scientific attitude, and the validity of these assumptions when the scientific attitude is applied to biological phenomena, including man, as well as to the physical world.


OBJECTIVE II. TO PROVIDE THE STUDENT WITH AN UNDERSTANDING OF THE DIFFERENT GENETIC MECHANISMS INVOLVED IN INHERITANCE.

In teaching genetics at the high school level many teachers either have not recognized, or have neglected to teach, multiple-factor inheritance as well as simple Mendelian inheritance. The meager amount of time that most teachers allocate to the teaching of genetics usually is not sufficient to cover more than Mendel's laws. The limitation of the presentation of genetics to a treatment of Mendel's laws results in giving the student a false impression of the genetic mechanism which form the basis of evolution. Most characteristics are not controlled by single gene pairs but nevertheless are of genetic origin. Such phenomena as incomplete dominance, gene interaction of many kinds, recombination, ploidy, mutations, chromosomal aberrations, and cytoplasmic effects are widespread. It should be the objective of the teacher to discuss as many as possible of those genetic phenomena which differ from simple Mendelian inheritance. The student should be given the experience of conducting laboratory experiments designed to demonstrate how the different genetic mechanisms involved in inheritance operate.
OBJECTIVE III. TO PROVIDE THE STUDENT WITH AN UNDERSTANDING OF THE NATURE AND THE CAUSES OF GENETIC VARIATION IN POPULATIONS (POPULATION GENETICS).

A knowledge, on the part of the student, of population genetics will help him to understand how evolution takes place. Population genetics is the study of those forces which tend to maintain or disturb (either temporarily or permanently) a given gene frequency in a population. The student should know what a population or gene pool is, how to determine the frequency of a gene in a population (Hardy-Weinberg Law), and what forces disturb the maintenance of a constant gene frequency within a population—mutations, natural selection, gene flow or migration, and genetic drift. A study of these basic principles of population genetics will give the student an understanding of how the mechanisms of evolution operate.

OBJECTIVE IV. TO PROVIDE THE STUDENT WITH AN UNDERSTANDING OF THE GENETIC MECHANISMS INVOLVED IN THE ORIGIN OF RACES AND SPECIES.

The student should acquire an understanding of how the interaction of the genetic mechanisms of mutation and genetic recombination (sexual reproduction), together with natural selection, and isolation (geographic and/or reproductive) results in the origin of races and species. These four
biological mechanisms are the cornerstones of evolution and together they constitute the neo-Darwinian concept of evolution. An understanding of how these mechanisms operate and the realization that they are operating today will help the student to comprehend the fact that evolution is occurring today. Evolution in action is an important biological concept that will help the student better understand the natural world of which he is a part. A knowledge of the biological mechanisms operating to produce evolution is essential if the student is to cope with future problems requiring accurate biological knowledge for their solution.

OBJECTIVE V. TO PROVIDE THE STUDENT WITH KNOWLEDGE OF THE HISTORY OF LIFE.

The history of life as represented by the fossil record supports the fact of evolution. The fossil record shows that there has been much organic change, accompanied by extinction, since life began on this planet.

The importance of presenting the distribution of organisms through time as evidence for the occurrence of evolution cannot be overstressed. The student should be made aware of the means by which fossils are formed, the biases and imperfections of the fossil record, and the evolutionary trends apparent in it. A discussion of the validity of the neo-
The Darwinian concept of evolution as it applies to the fossil record would help the student perceive how:

...the origin of genera and other higher categories, as well as the phyletic progressions usually characterized as macro-evolution, result from the continuation into geologic spans of time of the processes responsible for evolution on the racial and species level.15

OBJECTIVE VI. TO PROVIDE THE STUDENT WITH AN UNDERSTANDING OF PAST AND PRESENT HUMAN EVOLUTION.

Any discussion of human evolution should include a presentation of the fossil evidence for man's evolution.

The student must be made aware of the fact that the key to man's evolution has been his upright posture which has freed his hands for use as grasping organs, and made possible the coordinated evolution of hands, eyes, and brain.16

A presentation of how the human races have evolved should be included in a discussion of human evolution. The student will acquire a more objective attitude toward the problem of racism if the teacher points out that cultural differences are not inherited through genes and that racial groups are


not synonymous with cultural groups. An understanding of the origin and nature of the biological differences existing among human races will help the student in making personal decisions concerning the problem of racism.

An understanding that culture is an evolutionary force interacting with natural selection is essential if the student is to comprehend adequately how human evolution has occurred and is occurring. The fact that "The evolution of the things that man uses has largely taken the place of further specialisation of his body"¹⁷ should be presented to the student to help him understand how culture affects biological evolution.

No study of human evolution can be complete without a discussion of eugenics - the social control of human evolution. That man possesses the ability to control his own evolution is clearly evident from the fact that man has controlled and is controlling the evolution of domesticated plants and animals. A discussion of eugenics will help the student to realise the gravity of many of the social problems confronting mankind today.

Chapter IV

THE STATUS OF GENETICS AND EVOLUTION TEACHING AT THE HIGH SCHOOL LEVEL

There have been only four studies which have dealt directly or indirectly with the status of the teaching of genetics and evolution in high school biology. Two of these were concerned with the teaching of evolution only, while the other two were concerned with the whole subject matter area of biology. One of the latter surveyed general biology courses while the other surveyed advanced biology courses.

The study made by Riddle et al. of general biology courses in 1939-1940 contains little information on genetics. It states only that heredity is one of the three

18. E. Laba and E. Gross, op. cit.: 396-399.


22. O. Riddle et al., op. cit.: 65 and 66.
leading topics that a teacher would emphasise in general biology, and that genetic inequality of human beings was being taught by three-fourths of the teachers surveyed. An intensive study never has been undertaken to determine what subject matter areas in genetics, beyond simple Mendelian heredity, are being taught in general biology. Such a study, if undertaken in the near future, would probably demonstrate the poor state of the teaching of genetics in general biology.

It is interesting to note the study done by Lightner\textsuperscript{23} which was concerned with the subject matter content of advanced biology courses in large high schools. His study showed that the following subject matter areas in genetics were covered comprehensively by the teacher in an advanced biology course:

<table>
<thead>
<tr>
<th>Subject Matter</th>
<th>% of teachers giving subject-matter item comprehensive treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature of RNA</td>
<td>41.5%</td>
</tr>
<tr>
<td>Nature of DNA</td>
<td>43.0</td>
</tr>
<tr>
<td>Mendel's historic work</td>
<td>68.9</td>
</tr>
<tr>
<td>Nature of chromosomes and genes</td>
<td>86.6</td>
</tr>
<tr>
<td>Nature of alleles</td>
<td>72.6</td>
</tr>
<tr>
<td>Nature of linkage</td>
<td>73.3</td>
</tr>
<tr>
<td>Nature of crossing over</td>
<td>70.4</td>
</tr>
<tr>
<td>Nature of lethal genes</td>
<td>75.5</td>
</tr>
<tr>
<td>Nature of sex determination</td>
<td>68.6</td>
</tr>
<tr>
<td>Nature of mutations</td>
<td>78.5</td>
</tr>
<tr>
<td>Significance of genetics in evolution</td>
<td>74.6</td>
</tr>
</tbody>
</table>

\textsuperscript{23} J. Lightner, op. cit.: 13 and 17.
It would have been of value to have known just what specific subject matter the teachers presented when they treated comprehensively the significance of genetics in evolution. It is very discouraging to find that approximately one-fourth of the teachers surveyed by Lightner did not give a comprehensive treatment of the above mentioned subject matter areas of genetics in advanced biology courses in large high schools.

The studies made concerning the teaching of evolution in high school biology courses clearly indicate how inadequately evolution is being taught in our schools. Riddle, in his study of what is taught in high school biology, concluded:

The principle of organic evolution, seriously affected and restricted by religious views of individuals and communities, is taught to one or another extent by about 50% of the teachers who replied to this questionnaire. The data indicate that complete returns from the schools of the United States would show that evolution is taught in notably less than half of the high schools. Even when "taught" this principle is frequently diluted beyond recognition, or it is joined to traditional beliefs as to preclude a new ripple of thought.24

Two more recent studies by Morrison,25 and Laba and Gross,26 which were concerned specifically with the teaching of

24 O. Riddle et. al., op. cit.: 76.
25 D. Morrison, loc. cit.
26 E. Laba and E. Gross, loc. cit.
evolution in general biology, showed that, while most teachers discuss the topic, the discussion is incomplete and that the teachers themselves are confused concerning what evolution is and how it operates. It can be concluded on the basis of the three studies mentioned above that the teaching of evolution in general biology is unsatisfactory—the subject matter being incomplete, fragmentary and unsupported, for the most part, by supplementary materials.

The situation is appalling when one turns to the teaching of evolution in advanced biology courses in high schools. Lightner's study of large high schools has shown that only six per cent of the teachers give a comprehensive treatment of evolution in an advanced biology course. However, this small percentage is probably misleading. Lightner's study also showed that 11% of the biology teachers surveyed utilized Life by G. G. Simpson et al. as the textbook for the advanced biology course they were teaching. The subject matter content of this text is organized around the principles of evolution. Even so, it is highly lamentable that so few teachers attempt to provide a comprehensive treatment of evolution in advanced biology courses in high school.

27. J. Lightner, op. cit.: 17.

Professional biologists have criticized the poor status of the teaching of evolution in high school. Riddle states:

Can student or teacher, in high school or college, assume that biological science is being taught when the student is gaining no comprehension of the precise forces that have led to the living world as we now find it, including human existence as it earlier was and now is. 29

Muller, in his article "One Hundred Years Without Darwinism is Enough," has the following to say about the teaching of evolution:

It ill befits our great people, four generations after Darwin and Wallace published their epochal discovery of evolution by natural selection, to turn our backs on it, to pretend that it is unimportant or uncertain, to adopt euphemistic expressions to hide and soften its impact, to teach it only as one alternative theory, to leave it for advanced courses where the multitude cannot encounter it, or, if it is dealt with at all in a high school biology course, to present it as unobtrusively and near the end of the course as possible, so that the student will fail to appreciate how every other feature and principle found in living things is in reality an outgrowth of its universal operation....Surely the groping minds of boys and girls cannot be expected to piece together for themselves, with only a few clues here and there, that great evolutionary picture which before Darwin had eluded nearly all the creative thinkers of mankind. 30

Why are many students "shortchanged" when it comes to being exposed to what evolution is and how it operates (the


genetic mechanisms involved)? Why is this important phase of biology so neglected by their teachers? The studies by Riddle et al., Laha and Gross, and Morrison have pointed to three reasons: (1) religious opposition to the teaching of evolution; (2) lack of knowledge on the part of the teacher; and (3) lack of adequate textbooks. These three problems are discussed separately in the remainder of this chapter and the writer will suggest possible solutions to them.

THE PROBLEM OF THE RELIGIOUS OPPOSITION TO THE TEACHING OF EVOLUTION

Just how effective is the religious opposition to the teaching of evolution? The study made by Riddle et al. in 1942, of the teaching of general biology in high school, showed that 916 of the 3075 teachers surveyed either avoided evolution completely or treated the topic lightly in the classroom (843 of the 916 teachers taught in public schools). These teachers supplied 1,236 reasons for avoiding evolution or treating it lightly. These reasons were categorized as follows:

287 -- opposition by the majority of the community.
233 -- the teacher's personal belief.
109 -- opposition by the minority of the community.

90 -- opposition by the school administration.
73 -- opposition by the state legislature.
54 -- opposition by board of education.
381 -- other reasons (many of these could be classified as the teacher's personal belief, according to Riddle). 32

The fact that almost one-third of the teachers in Riddle's study either avoided evolution or treated it lightly because of religious opposition of one type or another demonstrates the strength of this type of opposition to the teaching of evolution. Eight per cent of all the teachers surveyed stated that they opposed the teaching of evolution because of their personal religious beliefs while other teachers inferred this by their replies. This indicates how deeply ingrained are antiscientific attitudes in some of the biology teachers who should be helping their students acquire scientific attitudes.

Two more recent studies on the teaching of evolution have verified the fact that approximately one-third of the teachers omit evolution completely or treat the topic lightly in the classroom. Laba and Gross found that eight out of 29 biology teachers surveyed in Essex County, New Jersey, omitted evolution completely, 33 while Morrison found that 33 out of 94 public school teachers surveyed in Oregon did not present

32  Ibid.
33  E. Laba and E. Gross, op. cit.: 396-399.
a planned unit about evolution in their biology course. Nineteen of these 33 teachers, however, estimated that they devoted an average of 7.8 class periods a year largely to evolution.34 Both of these studies pointed out that the personal religious beliefs of the teacher are important in determining whether or not evolution is taught in the classroom, and how it is presented if it is taught. Laba and Gross made the following conclusion:

Reflecting the attitudes of certain areas of society there are many teachers, at least in northern New Jersey, who are perplexed in their thinking on the subject of evolution. There must be many teachers who are unable to bridge the chasm between the indisputable discoveries of research scientists relative to the facts of organic evolution and their hostile emotions crystallised, perhaps, in early childhood by religious training. The fact that the topic of evolution is avoided in the classroom by so many teachers lends weight to our interpretation.35

Morrison, in his study of the teaching of evolution in Oregon schools, concluded that there was too much religion being taught with evolution in biology. He states:

It seems to the investigator there is too much religion brought in with the teaching of evolution. One of the popular approaches is, "Look at me! I believe in evolution and also in God. Why can't you?" Another approach is that religion is for telling why we are here, and that it is the purpose of science to tell how we got here.36

35. E. Laba and E. Gross, op. cit.: 399.
Religious opposition to the teaching of evolution has also resulted in the censorship of subject matter concerning evolution in high school texts. This will be discussed under the problem of inadequate textual materials, however.

Laba and Gross felt quite strongly about the religious opposition to the teaching of evolution as can be seen by their concluding remarks:

Are we teaching our youth to become critical thinkers who will appreciate the methods of independent scientific research, or, as practiced in the monolithic states, shall we teach, instead, certain areas of generally accepted and inoffensive information—diluted and digested—to the students, who will then accept them as a matter of course? Perhaps while rendering lip service to the first alternative, we are really manipulating the instruments of public education in order to perpetuate existing institutions and to reinforce popular opinions.

If one of our objectives is to produce a citizenry which is sensitive to the trappings of authoritarianism, then we, as educators, must demonstrate this hollowness by our critical evaluations in the classroom and in the textbook. Anything less than this—any blind worship of dogma, any stubborn refusal to acknowledge fresh or contradictory evidence—must inevitably lead to the type of science that plays the lackey to state or church.

Therefore, it is our contention that when scientific truths are not fearlessly expounded in classroom and textbook, the offending writer, editor, publisher, or teacher performs a disservice toward science, toward public school education, and toward the country itself.37

37 E. Laba and E. Gross, op. cit.: 399.
What can be done to overcome the problem of religious opposition to the teaching of evolution? That there is no simple solution to this problem is attested to by Mayfield:

A problem which is...less susceptible to systematic attack is that raised by religious opposition to the teaching of evolution. However unjustified scientists and some religious groups may consider such opposition, it is widespread and effective. It is firmly rooted in an essentially antiscientific approach to the natural world and is supported by law, by school boards whose members agree with the opposition, and by school administrators who dare not permit the use of controversial material in their schools. As a result, effective study of evolution is prevented in many communities. By interfering with the sale and use of textbooks, it, in effect, censors those that are most widely used. Colleges that are controlled by anti-evolutionist groups may not deal with evolution in their own biological courses, especially those general education courses most likely to be taken by future teachers. Thus the opposition also interferes with the development of teachers who are convinced that evolution is a fact rather than an invention of the devil working through irreligious scientists. 38

Mayfield then goes on to discuss some of the modes of action suggested by high school teachers to overcome opposition to the teaching of evolution:

Teachers who believe that the study of evolution is an essential part of the modern high-school biology course propose a number of modes of action to overcome opposition to teaching it. The more optimistic propose widespread efforts

to convince the public of the truth of evolution. They suggest talks to community groups by scientists and teachers, student-led panels before such groups, more popular articles in widely read periodicals, and other similar approaches designed to change the views of citizens. Others advocate adapting the classroom approach to the school and community situation in at least three different ways: (1) point out to students that, while some people, including perhaps some of them, do not accept the idea of evolution, it is important for an intelligent person to know what others believe and why, without necessarily agreeing with them; (2) teach evolution as applying to plants and animals but stop short of man and leave students to develop their own private opinions as to the universality of the process; (3) teach evolution under the name of "biological change" or "development," thus avoiding the controversial term. Some teachers consider the second and third methods essentially dishonest and unsuited to a science course. Others feel that the name used is unimportant and that it is the ideas that are essential. None of these approaches really solves the problem, and there seems little doubt but many biology teachers must continue to live with it.39

With the exception of the proposed plan to educate the public concerning evolution, the above suggested modes of action do not alleviate the problem of the many teachers who avoid completely the teaching of evolution or who are evasive in their treatment of the topic because of their personal religious beliefs.

Is there a conflict between evolution and Christianity? The teacher who either omits evolution completely or treats the topic lightly in the classroom must think so. Oscar Riddle, a staunch evolutionist, claims that there is a conflict

39. Ibid.
between evolution and Christianity:

Whatever the pretensions and formal statements of the various religions, they seem to be basically concerned with the origin, the nature (moral and other), and the destiny of man. That their spheres thus overlap those of biology, psychology, and sociology seems clear and certain.

As long as religion or religions presume to provide an interpretation of man, of nature, or of conduct—or, again, as long as religion or religions have a supernatural content—nothing can be more absurd than the contention that religion and science are distinct areas and free from conflict. The extent to which that absurdity is propagated, even by many of those now entrusted with the advancement of science and learning, may be a major indictment of much of the intellectual leadership of our day.40

Sir Julian Huxley, former Director General of UNESCO, reflects the opinion of many scientists in this statement concerning the conflict between science and religion:

In spite of the lull in the storm, the final battle between medieval systems [religious] and modern systems [evolutionary] of thought is yet to be fought out. The affair of Galileo was a matter of outposts; that of Darwin a heavy skirmish; but the main issues, in spite of all the smooth words, remain unreconciled.41

What is the philosophical basis for the conflicting views existing between science and Christianity concerning the origin and nature of the natural world including man? Science involves two philosophical assumptions—first, the


universe as a whole displays order; and second, man has reached the point where he can examine, interpret, and understand that order.\textsuperscript{42} The scientist, then, operates on the further assumption that natural events have natural causes, and that he can determine what these natural causes are. These philosophical assumptions on the part of science have been upheld time and time again by scientific discoveries.

It is when science, based on these philosophical assumptions, attempts to explain nature and man in particular, that Christian theology rebels. Scientific laws which describe the actions of nature are repugnant to some Christian theologians because these scientific laws include descriptions of man which conflict with their concept of God and man. Therefore these schools of Christian thought have rejected the validity of these assumptions of science. Instead, they stress the role of the supernatural operating outside of natural laws. This, then, is probably the philosophical basis for the conflict that exists between science and Christianity. It is probably the major reason why teachers, because of their personal religious beliefs, are evasive in their treatment of evolution or avoid the topic completely in the classroom.

Many teachers have difficulty separating fact from theory in the field of evolution. Evolutionary philosophy, as

championed by such biologists as Huxley and Riddle, has become a very confusing issue for teachers to handle, both inside and outside of the classroom. David Lack, in his book, *Evolutionary Theory and Christian Belief: The Unresolved Conflict*, has attempted to separate fact from theory in evolution, and to assess the relationship of Darwinism to Christianity. His conclusions which are listed below should be of help to the teacher:

1. Animal evolution is an historical fact, and fossils have been found which link man with ape-like forms, so that there is every reason to hold that man evolved from other animals.

2. Various statements concerning natural history in the first three chapters of Genesis are factually wrong. But these chapters should be regarded as allegorical, or at least as allegorical history, which is probably what their writers intended them to be. This need in no way lessen their spiritual truth, which is concerned with matters that come outside science.

3. Evolution is comprehensible in terms of the natural selection of hereditary variations, and so far as known, does not take place in any other way. The variations are random in relation to the needs of the animal, and the directions of evolution are determined by natural selection.

4. For this and other reasons, the concept of either an internal urge or an external Life Force directing the course of evolution is inadmissible. It is also unnecessary and undesirable to postulate that animal evolution has been helped by supernatural interferences with natural laws.

5. The fear that the course of evolution has been entirely 'fortuitous' or 'random' is due to a misunderstanding, since evolution has proceeded in accordance with natural laws. The alternative fear that its course has been rigidly predetermined
by mechanistic forces is likewise due to a mis-
understanding, since evolution has taken a par-
ticular historical course; and the true nature of
scientific laws and of historical sequences, and
their connection with causation and determinism,
are hard problems in philosophy on which the
theory of evolution throws no special light.

6. That the universe appears to be run according
to natural laws does not, in itself, provide a
compelling argument for either theism or atheism,
though such a claim has been made both ways.
While, too, some have vividly felt the existence of
God from the grandeur of the universe or the
beauty of living things, others have felt nothing
of the kind.

7. All should accept the findings of science in
the field of science. The agnostic T. H. Huxley --
'follow humbly wherever nature leads' -- and the
parson Charles Kingsley -- 'science is the Voice
of God' -- speak to the same effect on this point.
Hence though it may be hard for some Christians to
reconcile natural selection with the God of mercy,
or for some secular humanists to reconcile man's
evolution by natural selection with morality or
beauty, such difficulties provide no valid reason
for doubting scientific evidence.

8. On the other hand, it is important that the
claims made by scientists in the name of science
should relate to genuinely scientific matters, and
that when they really refer to philosophical prob-
lems, this should be made clear. In particular,
the claim that man has evolved wholly by natural
means is philosophical and not scientific.

9. The theory that man's moral behavior has been
evolved, directly or indirectly, by natural selec-
tion fails to account for the essential aspects of
the moral experience. Yet no other means of evol-
ution is admitted by biologists.

10. Science has not accounted for morality, truth,
beauty, individual responsibility or self-awareness,
and many people hold that, from its nature, it can
never do so, in which case a valid and central part
of human experience lies outside science. But if
man evolved wholly by natural means, it might be supposed that all human nature should be interpretable in scientific terms. It might therefore be argued that man cannot have evolved wholly by natural means. But others would disagree, since there are unbridged gaps and unreconciled contradictions in every view of the meaning or lack of meaning of the universe. 43

Lack's conclusions clearly point to the fact that, while evolutionary biology has and is forcing Christian theology to modify many of its doctrines concerning the concept of the Christian God and the origin and nature of man, it does not provide all of the answers either. However, Lack reminds the reader that the reality of the fact of evolution and the mechanisms of evolution cannot be denied.

Most teachers who have difficulty accepting the reality of evolution are usually quite troubled by the problem mentioned by Lack in his fifth conclusion, that of whether to consider evolution as a random process operating by chance alone, or as a non-random process operating within the confines of natural laws. The fact that the way in which the teacher looks at evolution as a process is important in formulating his or her philosophy of life is attested to by Rensch, who states:

On the one hand, evolution may be looked at as an undirected unique historical process; on the other

hand, it seems to be determined by a great number of rules and laws. A decision between these two conclusions will be very important to the philosophy of life.44

Rensch, in the same paper, presents an excellent discussion of the laws of evolution, which should be very helpful to the teacher who is perplexed with this problem.

Lack, in his eighth, ninth, and tenth conclusions, clearly points out that many of the so-called scientific statements concerning the problem of man's nature are in reality more philosophical than scientific at the present time. The writer believes that if the teacher is made aware of the philosophical problems involved and acquires the ability to separate fact from theory, he will have overcome many of the obstacles which prevent his giving an adequate presentation of what evolution is and how it operates.

There are essentially four philosophical viewpoints which have been utilized to look at the relationship between evolution and religion in western civilization. The teacher should become familiar with all four of these viewpoints in order to understand better the philosophical and religious problems engendered by the findings of evolutionary biology.

The viewpoint of evolutionary philosophy has been expounded by Sir Julian Huxley in his book, Knowledge, Morality

and Destiny. 45 C. H. Waddington in his book, The Ethical Animal, 46 attempts to establish a basis for modern day evolutionary ethics.

The viewpoint of liberal Christian theology is best expressed by two Canons of the Church of England, Canon C. Raven, and Canon A. Smethurst, in their books, Natural Religion and Christian Theology 47 and Modern Science and Christian Beliefs 48 respectively. The Roman Catholic theological viewpoint can be found in Theology and Evolution edited by E. Messenger. 49 A more up-to-date account can be found in a paper presented by Father F. Ewing 50 at the Darwin Centennial Celebration at the University of Chicago in 1959.


The conservative Christian theological viewpoint consists, in reality, of many diverse views concerning evolution. On the whole, conservative Christian theology has been the seat of the most violent opposition to evolution. Two books, *Creation and Evolution* by J. Lever (a biologist of the Christian Reformed faith, and *Evolution and Christian Thought Today* (a symposium written by scientists of several different conservative Protestant Christian faiths) edited by R. Mixter, have made the first serious attempts to reconcile conservative Christian beliefs with the facts of evolution. The conservative Lutheran viewpoint is represented by a symposium edited by P. Zimmerman. The ultra-conservative Christian theological viewpoint is championed by J. Whitcomb and H. Morris who attempt to validate scientifically the theological doctrines of biblical creationism and catastrophism.

Additional books which discuss the relationship of


evolution to religion are listed under the heading of Religious, Philosophical, and Political Aspects of Genetics and Evolution in Appendix I.

The problem of overcoming the teacher's personal religious objections to the teaching of evolution must be handled very carefully by science educators and others trying to solve this problem. One cannot sit idly by in the hope that such teachers will retire in the near future and be replaced by teachers who are not opposed to teaching evolution. Many colleges supported by religious organizations are producing high school biology teachers today who are unscientific in their attitude toward the fact of evolution and how evolution operates. The writer does not think that this problem can be solved completely in the immediate future but it certainly can be reduced. The following modes of attack may produce some change in attitude toward evolution on the part of the teacher or prospective teacher who opposes the teaching of evolution because of personal religious beliefs.

First, college instructors of biology should not take for granted that the student will look at evolution from the scientific point of view, but rather should make a concerted effort to help the student develop scientific attitudes toward the fact of evolution and the operation of the mechanisms of evolution, particularly in man.
Second, prospective teachers taking courses designed specifically to prepare them to teach biology should be required to read at least one of the books written concerning evolution in relation to religion, and they should be required to make a critical analysis of the book. Some of the students should be asked to read their papers in class. Such an oral presentation can be of great value if the instructor makes critical comments concerning the scientific validity of the student's statements. The presentation and discussion of such papers should accomplish two things: (1) to demonstrate to the students how difficult it is, because of preconceived ideas, to make critical analyses that are scientifically valid of books on the relationship of religion to evolution, and (2) to help make the students aware of the assumptions implicit in evolutionary philosophy, and the gravity of the differences existing between the findings of evolutionary biology, and the religious doctrines expounded by the more conservative schools of Christian theology.

Third, instructors of biology can capitalize on the fact that some of the high school biology teachers who have been indoctrinated with unscientific attitudes toward evolution in church colleges take in-service training courses at public colleges and universities. Most college instructors of biology are already aware of the difficulty of trying to
teach evolutionary concepts to a person who is hostile toward such concepts because of personal religious beliefs. Often there is a complete breakdown in intellectual communication between the college instructor and the high school teacher because of the barriers created by conflicting religious and scientific attitudes. The writer suggests that the college instructor of biology refer such a student to one or more books, such as that written by David Lack,\textsuperscript{55} on the relationship of evolution to Christianity. This type of approach should help the high school teacher to develop a more scientific attitude toward evolution which should favorably affect the teaching of evolution by such a person.

THE PROBLEM OF LACK OF KNOWLEDGE ON THE PART OF THE TEACHER

The studies made by Morrison, 56 and Laba and Gross 57 have demonstrated that teachers are confused in their thinking concerning what evolution is and how it operates. The teachers surveyed in these studies had difficulty in separating fact from theory in the subject matter area of evolution. For example, Morrison found that only 24 out of 96 teachers considered evolution to be a fact. 58 Organic evolution—organic change—is a historical fact. Only man's explanation of how evolution is operating and has operated is a theory—a theory which is beginning to demonstrate the same validity in biology as the atomic-molecular theory has in the physical sciences. The confused thinking of teachers concerning what evolution is and how it operates is partly due to their lacking sufficient knowledge concerning evolutionary biology.

This lack of knowledge concerning genetics and evolution on the part of the teacher is probably the result of two causes: first, the teacher's inadequate educational background in these biological concepts; and second, the rapid


57. E. Laba and E. Gross, op. cit.: 396-399.

expansion of the fields of knowledge encompassed by genetics and evolution which makes it difficult for the teacher to keep up with the latest advances.

The problem of an inadequate educational background in the concepts of genetics and evolution will be considered first. Biology departments in colleges have been rather slow in recognizing the major positions that these unifying concepts now occupy in biology. Some biology departments do not require prospective biology teachers to take courses in one or both of these areas. The emphasis continues to be on offering and requiring courses in descriptive biology.

One of the first steps that must be taken to overcome the problem of poor teaching of genetics and evolution is to make sure that prospective teachers get the type of education that will enable them to teach modern biology—biology based on the four unifying concepts. The required biology curriculum for teachers in all biology departments in college must have courses—concerned with these unifying concepts as the core of their program. Such a program is proposed by William Grant, Jr. and C. B. Saul, who stress the value of such a core for any biology student.

The inclusion of an extensive core is defended on the grounds that it provides a fund of knowledge that may be useful background for any specialization the student selects in graduate or professional school. In all subfields of biology there is a need for people capable of integrating concepts in their research and appreciating the applicability of results.
obtained by others. These qualities are not likely to be acquired if a man has wide gaps in his training. For example, who can say that a man working on problems of conservation will not need to use concepts drawn from physiology, biochemistry, or genetics in his studies?

The program advocated by Grant and Saul is designed to train biologists as scientists. In setting up curricula for prospective high school biology teachers it is important that college educators consider the fact that the professional biology teacher should be a trained scientist as well as a teacher. It is encouraging to note that many colleges and universities are reorganizing their undergraduate biology curricula in order to place increased emphasis on the interrelationships and unifying concepts that exist in biology.

It must be remembered that many teachers now teaching high school biology did not prepare themselves to teach high school biology while they were in college. Because of poor certification requirements and the willingness of high school superintendents to hire persons who lack the necessary background in biology to teach the subject, many persons now teaching biology lack an adequate knowledge of genetics and evolution.

Inadequate undergraduate education is but one cause of the lack of knowledge on the part of the teacher. It has been only recently that the major principles and concepts

have been clarified. The teacher in the field finds it extremely difficult to keep abreast of the latest developments in biology, and particularly in the fields encompassed by genetics and evolution. There have been two methods of attack open to teachers who desire to keep up with the latest developments in biology—first, that of taking advanced courses in biology at colleges and universities; and second, that of self-education.

There has been a definite increase in the number of teachers taking advanced courses in biology at colleges and universities. This trend is very encouraging. However, most biology departments offer few courses in genetics and evolution and those that are offered are usually taught at times when the teacher finds it impossible to take them. More courses are needed in genetics and evolution designed for teachers and prospective biological scientists. These courses should be taught evenings, Saturdays, and in summer sessions in order to make it more convenient for the high school biology teacher to enroll in them. It is encouraging to note that several of the National Science Foundation summer institutes for biology teachers have devoted either the entire summer session to genetics and evolution or have included a genetics or evolution course in their programs. Too often, field biology is stressed by biology departments during summer sessions to the point where teachers taking advanced training in biology during the summers do not receive any
additional education in genetics and evolution. This deficiency should be avoided both by the teacher and by his academic advisor when planning an advanced biology program.

Most biology teachers desire to keep up to date as much as possible on their own. Self-education in the past has been somewhat difficult for the teacher because of the cost of reference works in biology. Also, the teacher often has been overwhelmed by the large number of books being published each year, and has had difficulty determining which would best suit his needs and which would not. The increasing number of inexpensive paperback reference books being published today is a boon to the teacher who desires to keep abreast of the latest developments in biology.

The writer has prepared the following annotated list of books, both paperbound and hardcover, designed to help the teacher keep informed concerning recent developments in genetics and evolution. These books provide an excellent nucleus for an inexpensive personal reference library.


Additional books on genetics and evolution are listed in Appendix I. This bibliography will help the teacher find books containing more specialized information on genetics and evolution.

The writer has prepared other bibliographies designed to help the teacher overcome his lack of knowledge in the fields of genetics and evolution. Appendix II contains a listing of the major articles on genetics and evolution that have appeared in lay magazines and semi-popular science magazines, such as *Scientific American* and *Science*, for the past ten years. These articles can provide the teacher with an excellent means of keeping up to date on genetics and evolution.

Appendix III is a list of articles and books on laboratory experiments in genetics. Many biology teachers in the
field never have had any experience working with the fruit fly, *Drosophila*, an organism that can be utilized on the high school level to demonstrate the principles of genetics. The bibliography prepared by the writer is designed to help the teacher find information on how to utilize *Drosophila* in high school laboratory experiments in genetics.

Appendix IV, which lists important papers concerning the neo-Darwinian concept of evolution that have appeared in research journals in the past few years, will help the teacher gain a better comprehension of modern evolutionary thinking.
PROBLEM OF INADEQUATE TEXTBOOKS

The inadequacy of the treatment given genetics and evolution in high school biology texts can be determined easily by a check of any four or five textbooks used in general biology courses. Morrison has made an analysis of the information about evolution in high school biology texts. Morrison and Laba and Gross have pointed out the inadequate treatment given evolution by such textbooks.

Laba and Gross have pointed to the role that religious censorship probably plays in the selection of information concerning evolution by high school biology textbook writers and publishers:

Although there are still regions in the United States in which the theory of evolution may not be explained and where texts must have all material relative to that subject excluded, New Jersey has never legislated against such teaching. Yet even without legal assault, many textbooks used here are inadequate and evasive in their treatment of organic evolution.

The names 'Darwin' and 'evolution' are anathema; there seems to be a tacit conspiracy to avoid their use in print....More than one-half of the textbook writers are caught on the triple pronged horns of a dilemma; (a) their fear of the fancied or real

60. D. Morrison, op. cit. 64pp.

61. Ibid.

hostility of segments of the population still influenced by the orthodox cosmogony that is deeply ingrained in the cultural heritage of the western world; (b) their subservience, perhaps, to the pressures exerted by publishers anxious to avoid criticism and to make sales; (c) the undoubted respect of textbook writers for the countervailing spirit of free scientific inquiry which demands a natural explanation for every natural event. 63

The following quotation from Muller demonstrates the extremes to which authors will go in attempting to avoid religious censorship while presenting a discussion of evolution:

The text called 'Modern Biology' which has been assigned in many high school classes in Indiana and elsewhere fails to contain the word evolution in the index or anywhere else. It does, however, in the next-to-the-last chapter have a moderately acceptable discussion of evolution, without using the word. This treatment comes at too late a point to allow consideration of all other parts of biology as manifestations of evolution. Moreover, the words 'racial development' are given, in heavy print (p. 655), as the term by which this principle of nature is known. 64

The lack of adequate textbooks soon will become a problem of the past if recent developments are any indication of current trends. The advanced biology textbook, Life, by Simpson, Pittendrigh, and Tiffany 65 is the first biology

63. Ibid.: 399.
64. H. J. Muller, op. cit.: 307.
textbook to be utilized at the high school level that stresses the principle of evolution throughout all of its pages. Lightner, in his study of advanced high school biology, found that 11 per cent of the advanced biology courses that he surveyed utilize this text as the primary textbook for the course, while an additional 15 per cent of the courses use it as one of the principle reference books. 66

All three of the experimental texts—Green, Blue, and Yellow Versions—produced by the American Institute of Biological Sciences Curriculum Study place extensive emphasis on the unifying concepts of genetics and evolution. These experimental texts, designed for tenth grade biology, emphasize the concepts of genetics and evolution as being basic to any understanding of biology. The writer will briefly discuss the subject matter content involving genetics and evolution in each of the three versions. It must be remembered that the versions that the author is reviewing are experimental and are scheduled to be revised during the summers of 1961 and 1962.

In the opinion of the writer, the experimental Green Version, produced under the direction of Marston Bates, 67 contains the poorest presentation of genetics and evolution of

66. J. Lightner, op. cit.; 6 and 9.

the three experimental texts. While the Green Version contains an excellent account of the history of life on this planet, it lacks any discussion of the mechanisms by which evolution operates. The subject matter area of genetics follows that of evolution rather than preceding it. This makes it difficult for the student to acquire any idea as to how evolution has occurred. The genetics unit is short and lacking in information on the vital topic of population genetics. The student is given no suggestion as to how gene frequencies are maintained or changed in populations, and because of this he is left without any knowledge of the genetic basis for the origin of races and species.

The experimental Blue Version, produced under the direction of Ingrith Deyrup,68 develops the fundamental biological concepts with emphasis on the ideas and experimental approach of physiology and biochemistry. This version contains an excellent presentation of genetics. It discusses many types of inheritance as opposed to stressing the "one-gene-one trait" type of inheritance so often taught in tenth grade biology. The basic concepts of population genetics are presented to the student in an excellent manner. This version also contains excellent discussions of the mechanisms of evolution, the differences existing between organisms, and

the patterns of evolutionary change. This version covers genetics and evolution to a depth that far exceeds the coverage given these concepts in any introductory high school biology text previously published.

The experimental Yellow Version, produced under the direction of John Moore,\textsuperscript{69} contains the same subject matter dealing with genetics as does the Blue Version, thus providing the same excellent treatment of the concepts of genetics. The discussion of the mechanisms of evolution following the genetics unit introduces the student to the factors which cause organic change. The presentation of the paleontological evidence for evolution and evolutionary trends is followed by two very pertinent essays—one on the evolution of man and the other on the dawn of agriculture and the cultural evolution of man. Such a presentation of genetics and evolution will certainly stimulate the student's curiosity concerning the natural world, and will help him develop scientific attitudes toward all of life.

While these three Biological Sciences Curriculum Study experimental texts will be revised during the summers of 1961 and 1962, the emphasis on such unifying concepts as genetics and evolution is very clear. The American Institute of Biological Sciences film series for tenth grade biology shows

the same increased emphasis on the unifying concepts of gen-
etics and evolution. The teacher in the field, however, will need to know about supplementary materials in order to help students to explore the fields of genetics and evolu-
tion beyond the scope of the texts or film series.

In the area of supplementary materials for teaching genetics and evolution the teacher is very fortunate in hav-
ing a vast array of material on which to draw. It has been only recently that the number of reference books, excellent magazine articles, and films on genetics and evolution has become extensive. In order to help the teacher in selecting supplementary material for use when teaching genetics and evolution on the high school level, the writer has prepared selected lists of the material available in all three of these areas.

Appendices I and II, mentioned in the previous section, will be an aid to the teacher searching for supplementary reading materials to use in teaching high school biology. Appendix V lists films on genetics and evolution, most of which have become available only within the last two or three years, and which are designed to cover specific topics of genetic and evolutionary interest.
CONCLUSION

(1) A knowledge of genetics and evolution can and must be made a part of the liberal education that every high school student receives. A knowledge of what evolution is and how it operates will enable the student to better understand the problems with which he will be confronted for the rest of his life. (2) All of the studies which have surveyed the teaching of genetics and evolution at the high school level have shown that neither of these subjects gets adequate attention in the classroom. (3) The studies reviewed in this thesis point to three problems that have contributed to the poor teaching of genetics and evolution: a) religious opposition, b) lack of knowledge on the part of the teacher, and c) lack of adequate high school biology textbooks.

The problem of religious opposition is the most difficult to solve owing to the fact that many teachers, because of their personal religious beliefs, either treat evolution lightly or evade the topic altogether in the classroom. The writer has suggested several ways to help the prospective or in-service teacher develop a more thoroughly scientific attitude concerning the facts of evolution and the operation of the mechanisms of evolution. This will enable him to provide his students with a more adequate presentation of
The writer has discussed ways in which college educators are attempting to solve the problems of the lack of knowledge on the part of the teacher and lack of adequate textbooks. The writer has prepared five appendices designed to help the high school teacher overcome his lack of knowledge and to provide him with information concerning supplementary materials that can be used in teaching genetics and evolution.
APPENDIX I. A SELECTED ANNOTATED BIBLIOGRAPHY OF REFERENCE BOOKS ON GENETICS AND EVOLUTION

This selected bibliography of reference books on genetics and evolution is designed to help the teacher select books for his high school library, recommend the purchase of pertinent reference books by the local public library, and find reference works on topics which he is in need of information on. The following numerical key is used to indicate the writer's recommendations concerning the purchase of reference books for high school and community libraries.

1 -- book recommended for use as a reference by high school students enrolled in an introductory biology course.

2 -- book recommended for use as a reference by high school students enrolled in an advanced high school biology course.

3 -- book recommended for purchase by the local public library.

The reference books are listed according to the following subject matter headings:

Behavior, genetics and evolution of
Biogeography
Cytogenetics
Drosophila, genetics and evolution of
Eugenics
Evolution, reference works
Evolution, textbooks
Genetics, reference works
Genetics, textbooks
Historical background of genetics and evolution
Human evolution  
Human genetics  
Microbial genetics  
Natural selection  
Paleobotany  
Paleozoology  
Religious, philosophical, and political aspects of genetics and evolution

BEHAVIOR, GENETICS AND EVOLUTION OF


BIOGEOGRAPHY

See also Paleobotany, paleozoology.


**CYTOGENETICS**


**DROSOPHILA, GENETICS AND EVOLUTION OF**


EUGENICS

See also Human Genetics.


EVOLUTION - REFERENCE WORKS

See also various other headings.


EVOLUTION, TEXTBOOKS ON


GENETICS - REFERENCE WORKS

See also various other headings


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Staff of University of Texas M. D. Anderson Hospital, and Tumor Institute (eds.) 1959. *Genetics and Cancer.* University of Texas Press, Austin, 459pp.


GENETICS, TEXTBOOKS ON


**HISTORICAL BACKGROUND OF GENETICS AND EVOLUTION**

See also Religious, Philosophical and Political Aspects of Genetics and Evolution; etc.


**HUMAN EVOLUTION**

See also Human Genetics, Natural Selection.


**HUMAN GENETICS**

*See also Human Evolution; Natural Selection; Eugenics.*


MICROBIAL GENETICS


NATURAL SELECTION

See also Human Evolution, Human Genetics.


PALEOBOTANY

See also Biogeography.


PALEOZOOLOGY

See also Biogeography.


RELIGIOUS, PHILOSOPHICAL, AND POLITICAL ASPECTS OF GENETICS AND EVOLUTION
See also Historical Background of Genetics and Evolution.


APPENDIX II. A SELECTED BIBLIOGRAPHY OF MAGAZINE ARTICLES ON GENETICS AND EVOLUTION

The following selected bibliography of magazine articles on genetics and evolution was prepared primarily for use in an advanced high school biology course. The bibliography can be used for three purposes: (1) assigning of outside readings to students; (2) referring students to articles where they can get additional information on a particular topic in which they are interested; and (3) aiding the teacher in keeping informed of advances in the rapidly-expanding fields of genetics and evolution. The magazine articles were included in the bibliography only if they served one or all of the above three purposes.

The articles included in the bibliography cover a period from January 1950 to March 1961, and are taken from magazines that are indexed in the Reader's Guide to Periodical Literature and from journals addressed to teachers (The American Biology Teacher, School Science and Mathematics, and Turton News). The articles vary in difficulty from those the average student can comprehend readily to those that even the better student and teacher may find difficult. The difficulty of the article can usually be determined by the magazine in which it appears. Those articles appearing in such magazines as Life, Natural History, or National Geographic Magazine can easily be assigned as outside readings to students taking introductory
high school biology while most of the articles appearing in such magazines as *Science* and *Scientific American* are more likely to be of most use to those students taking advanced high school biology. The periodicals in which these articles are found should be in most high school or community libraries. The articles are listed according to the following subject matter headings:

Behavior, evolution of
Biogeography
Biochemical evolution
Chromosomes
Cytology and evolution
Cytoplasmic inheritance
Developmental genetics and embryology
Domestication, evolution and genetics of
Eugenics
Evolution, animal
Evolution, general articles on
Evolution, inorganic
Evolution, plant
Genetic control of the cell
Genetics and cancer
Genetics, general articles on
Genes
Historical background of genetics and evolution
Human evolution
Human genetics
Microbial genetics
Natural selection
Origin of life
Paleobotany
Paleoecology
Philosophical, political, and religious aspects of
   genetics and evolution
Radiation genetics
Radiation genetics of man
Radiocarbon dating
Speciation
BEHAVIOR, EVOLUTION OF

See also Human Evolution.


BIOGEOGRAPHY

See also Paleobotany; Paleozoology.


**BIOCHEMICAL EVOLUTION**

See also Origin of Life


**CHROMOSOMES**

See also Genes.


CYTOLOGY AND EVOLUTION

See also Biochemical Evolution.


CYTOPLASMIC INHERITANCE

Anonymous. 1961. Among paramecia it has been discovered that cell structure may control inheritance. Science Digest, 48 (February): 61-62.


DEVELOPMENTAL GENETICS AND EMBRYOLOGY


DOMESTICATION, EVOLUTION AND GENETICS OF


EUGENICS

See also Human Evolution; Human Genetics; and Radiation Genetics of Man.


EVOLUTION, ANIMAL

See also Biogeography, Domestication; Human Evolution; Paleozoology; Speciation.


Dovey, E. S. 1954. The end of the moa. Scientific American, 190 (February): 84-90.


EVOLUTION, GENERAL ARTICLES ON


EVOLUTION, INORGANIC


**EVOLUTION, PLANT**

See also Biogeography; Domestication; Paleobotany.


**GENETIC CONTROL OF THE CELL**

See also Developmental Genetics and Embryology; Genes.


GENETICS AND CANCER

See also Radiation Genetics; Radiation Genetics, Human.


GENETICS, GENERAL ARTICLES


GENES

See also Developmental Genetics and Embryology; Genetic Control of the Cell; Chromosomes.


HISTORICAL BACKGROUND OF GENETICS AND EVOLUTION

See also Philosophical, Political, and Religious Aspects of Genetics and Evolution.


HUMAN EVOLUTION

See also Eugenics; Human Genetics; Philosophical, Political and Religious Aspects of Evolution and Genetics.


(February 27): 70-83.

1956. Growth of society. Life, 40


Life, 40 (June 4): 80-96.


HUMAN GENETICS

See also Eugenics; Human Evolution; Radiation Genetics of Man


Glass, Bentley. 1953. The genetics of the dunkers; genetic drift. Scientific American, 189 (August): 76-80.


**MICROBIAL GENETICS**

See also Genes.


**NATURAL SELECTION**

See also Human Evolution; Speciation; etc.


**ORIGIN OF LIFE**

See also Biochemical Evolution.


**PALEOBOTANY**

See also Biogeography; Radiocarbon Dating.


**PALEOZOOLOGY**

See also Biogeography; Radiocarbon Dating.


Glaessner, Martin F. 1961. Pre-cambrian animals. Scientific American, 204 (March): 72-78.


PHILOSOPHICAL, POLITICAL, AND RELIGIOUS ASPECTS OF GENETICS
AND EVOLUTION

See also Eugenics; Human Evolution; Human Genetics; and Natural Selection.


Scopes, John Thomas. 1961. The trial that rocked the nation. Reader's Digest, 78 (March): 137-144.


**RADIATION GENETICS**

See also Genetics and Cancer; Human Genetics, and Radiation Genetics of Man


RADIATION GENETICS OF MAN

See also Genetics and Cancer; Human Genetics; Radiation Genetics.


RADIOCARBON DATING


SPECIATION

See also Natural Selection; etc.


APPENDIX III. SOURCES OF INFORMATION CONCERNING THE PLANNING OF LABORATORY EXPERIENCES IN GENETICS AT THE HIGH SCHOOL LEVEL.

The value of laboratory experiences in genetics in helping the student grasp the principles of genetics cannot be overestimated. For example, the use of coins or marbles to demonstrate the laws of probability will enable the student to better comprehend this somewhat abstract principle as it applies to the genotype and phenotype ratios resulting from genetic crosses. The teacher will find the chapter on heredity in A Sourcebook for the Biological Sciences by Morholt, Branfwein, and Joseph (1958. New York: Harcourt, Brace and Co.) helpful in setting up elementary laboratory experiences in genetics at the high school level.

*Drosophila* is an excellent laboratory organism that can be used to demonstrate the mechanism involved in inheritance. Unfortunately, many teachers do not use *Drosophila* because they have not had the experience of working with it in college. These teachers need to be made aware of how easy it is to work with *Drosophila*. Some biology supply houses offer genetics kits containing the essential equipment that the teacher needs to carry out simple genetics experiments with *Drosophila*.

The better student desiring to do research in genetics will find that *Drosophila* offers some wonderful research opportunities. Several colleges, universities, and research centers (such as *Drosophila melanogaster* Stock Center, Institute for
Cancer Research, Philadelphia, Pa.) maintain hundreds of different cultures of Drosophila for use by scientific investigators. They would be glad to provide cultures of experimental strains of Drosophila to a promising science student desiring to do research in genetics. The teacher and student should not overlook the value of collecting wild strains of Drosophila in the vicinity of the school and breeding them in the laboratory.

The following selected bibliography of books and articles on genetics experiments and the handling of fruitflies should be of help to the teacher in planning and carrying out laboratory experiments in genetics utilizing Drosophila:


APPENDIX IV. SELECTED BIBLIOGRAPHY OF ARTICLES ON THE NEO-
DARWINIAN CONCEPT OF EVOLUTION

The neo-Darwinian concept of evolution is based on four
 genetic mechanisms—mutations, genetic recombination, natural
 selection, and isolation. Most high school biology teachers,
 while familiar with the various evidences for evolution, lack
 an adequate comprehension of how the genetic mechanism of evolu-
 tion interact with each other to produce organic change. One
 or more of the following misconceptions concerning the operation
 of these genetic mechanisms are held by many biology teachers:
 mutations are thought to be caused only be radiation; the role
 of genetic recombination in producing variation isn’t considered
 to be very important; natural selection is still being thought
 of as survival of the fittest or elimination of the unfit; genes
 are thought to be selected for or against rather than phenotypes;
 and isolation is thought to be necessary for any evolution to
 occur. Most genetics or evolution textbooks do not devote enough
time to clearing up the above misconceptions.

The following selected bibliography of reference articles
 on the neo-Darwinian concept of evolution is designed to help the
 teacher acquire a better understanding of evolutionary mechanisms.
The articles in the bibliography are grouped under the following
 headings: General Articles on the Neo-Darwinian Theory of Evolu-
tion; Mutation and Genetic Recombination; natural selection; and
 Isolation.
GENERAL ARTICLES ON THE NEO-DARWINIAN CONCEPT OF EVOLUTION


MUTATION AND GENETIC RECOMBINATION


NATURAL SELECTION


ISOLATION


APPENDIX V. A SELECTED LIST OF FILMS ON GENETICS AND EVOLUTION

Genetics and evolution probably are the two areas of biology that generate the most student interest and at the same time are the most difficult for the teacher to present and for the student to comprehend. The major problem in teaching these two concepts is that of helping the student associate the concepts with concrete situations. Without the proper class experiences the student will tend to consider these concepts as being very abstract and not closely associated with everyday happenings around him.

Films can help provide the student with experiences that will enable him to associate the concepts of genetics and evolution with concrete realities. If a film is to accomplish this goal the teacher must make a concerted effort to ensure that the film is used as a teaching device in the classroom. This can be accomplished by briefing the students on what to look for just before showing the film and discussing the scientific principles elucidated by the film immediately after its showing.

The teacher is very fortunate to have a large number of films available that are designed to convey specific principles of genetics and evolution to high school biology students. Films, if utilized properly, can be a great help to the teacher in overcoming the most difficult problem of teaching genetics and evolution: that of providing the student with experiences that will enable him to associate the concepts of genetics and evolution
with concrete situations.

The following is a selected list of films on genetics and evolution:

**GENETICS**


Basic nature of sexual reproduction. 15 min-sound-color or black and white. NET Film Service, Bloomington.

Biological techniques—genetics; techniques handling Drosophila. 3 min-sound-color. Biological Sciences Curriculum Study, Boulder.


Fact or fallacy. 30 min-sound-black and white. NET Film Service, Bloomington.


Heredity and environment. 30 min-sound-black and white. NET Film Service, Bloomington.

Heredity and the chromosome. 30 min-sound-color. NET Film Service, Bloomington.


It runs in the family. 30 min-sound-black and white. NET Film Service, Bloomington.


Many pairs of genes. 30 min-sound-black and white. NET Film Service, Bloomington.

Mendel's experiments. 30 min-sound-black and white. NET Film Service, Bloomington.

Mitosis and meiosis. 16 min-sound-color or black and white. Film Service, Bloomington.


Reproduction and heredity. 30 min-sound-black and white. NET Film Service, Bloomington.


Sexuality and variation. 30 min-sound-black and white. NET Film Service, Bloomington.


The thread of life. 60 min-sound-color. Bell Telephone System. (Available from regional offices).

Wisconsin corn hybrids. 35 min-sound-color. University of Wisconsin, Madison.
EVOLUTION

Camouflage in nature by form and color matching. 10 min-
sound-color. Coronet Films, Chicago.

Camouflage in nature by pattern making. 8 min-sound-color.
Coronet Films, Chicago.

Darwin and evolution. 30 min-sound-color. American Insti-
tute of Biological Sciences. McGraw Hill Book Co., New
York.

Darwin centennial celebration documentary movie. Sound-
color. Encyclopedia Britannica Films, Inc., Wilmette,
Illinois.

Evolution of the vertebrates. 30 min-sound-color. American
Institute of Biological Sciences. McGraw Hill Book Co.,
New York.

Fingers and thumbs (development of man's hand). Sound-black

The fossil story. 10 min-sound-color. Shell Oil Co.,
Chicago.

History of the horse in North America. Sound-color. Uni-
versity of California, Berkley.

The history of life. 30 min-sound-color. American Insti-
tute of Biological Sciences. McGraw Hill Book Co., New
York.

How living things change. 11 min-sound-color or black and
white. Coronet Films, Chicago.

In the beginning (story of Grand Canyon). Sound-color. Mod-

Natural Selection: Part I. 30 min-sound-color. American
Institute of Biological Sciences. McGraw Hill Book Co.,
New York.

Natural Selection: Part II. 30 min-sound-color. American
Institute of Biological Sciences. McGraw Hill Book Co.,
New York.

Organisms in time. 30 min-sound-color. American Institute


Our changing world. 60 min-sound-color. Ott and Methodist.


Prehistoric times: the world before man. 10 min-sound-color or black and white. Coronet Films, Chicago.
